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A

PRACTICAL TREATISE

ON THE

CONDENSATION OF STEAM;

CONTAINED IN

262 PAGES OF LETTER-PRESS, ILLUSTRATED WITH 212 ENGRAVINGS.

BY N. P. BURGH,
ENGINEER.

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PREFACE.

The preface of a work is practically the postscript in the wrong place, because no author, who writes to improve as he proceeds, can at the commencement of his labours say how much he can do. Of course the little portion he has allotted in the narrowness of his first conclusion can be stated, but the enlargement of his ideas must be for a future explanation. Similarly also, in writing on a scientific subject, the mind expands as the pen records, and thus improved ideas are developed. Analogous with these remarks has been my experience with the contents of this work, which are arranged as follows:—

In Chapter I. the introduction of the Condensation of Steam has been explained and illustrated by nine illustrations, with a record, taken from the most reliable sources, of the practical results obtained, together with the difficulties that had to be overcome.

Proceeding from that to Chapter II., the modern Condensers for Land Beam Engines have been dilated on, and illustrated by eight of the most improved examples now in use, and also the pumps and valves in connection.

Chapter III. contains six different arrangements of Condensers and Fittings for Oscillating Paddle-Wheel Marine Engines; and in Chapter IV. the arrangements for Horizontal Screw-Propeller Engines have been largely represented by twenty-three illustrations.

The Surface Condensers I noticed next, commencing in Chapter V. the Tubular arrangements, of which there are nine examples worthy of attention.

Then came the different methods for Packing the Tubes in Chapter VI., which reached the surprising number of *seventeen,* whereas the general belief is that there are about one-third of that number only, but I have shown otherwise for practical use.

Surface Condensers for Oscillating Paddle-Wheel Engines are next explained, and illustrated by four different arrangements in Chapter VII. This number, doubtless, appears small; but as there are only five vessels so fitted, it will be sufficiently explained.

In Chapter VIII. there are seven illustrations of Surface Condensers for Vertical Inverted Screw-Propeller Engines; and in Chapters IX. and X. eighteen examples for Horizontal Engines of the Direct and Return-Action types.

The arrangement of the Pumps and Valves for Marine Engines comprises Chapter XI., and several illustrations in other chapters, making altogether twenty-seven examples; and those for Beam Land Engines, nine examples in Chapter XIV.

I treated in detail the connection of Pump Valves for Marine Engines in Chapter XII., to the extent of fourteen different arrangements; also Pump Motion and Pistons received attention by six illustrations.

The supplementary details or fittings requisite with Condensers are explained in Chapter XIII., and consist of six illustrations of Injection Valves, three Snifting Valves, two Kingston Valves, and four Water Discharge Valves.

The most novel system of Condensation being that without an air pump, or by the Ejector, in Chapter XV. I fully investigated it, and illustrated thirty-two examples, all different and all demanding notice. This did not include either the "outside" the hull system, of which I show three kinds, and four of the condensation of steam by air.

Locomotive engines have lately been fitted with Condensers, and in Chapter XVI. there are fifteen illustrations of the arrangements and details in actual practice.

The principles of Condensation have, of course, not escaped my notice, and therefore in Chapter XVII. the subject has been thoroughly investigated, commencing with the constituent parts of steam, and following on to its formation, expansion, and condensation.

The Rules and Tables relating to condensers of all classes are contained in Chapter XVIII., after which is a complete Index of the Illustrations, the headings being arranged alphabetically.

I have thus put what I have had to say on this matter into 262 pages, and illustrated it with 212 practical examples.

N. P. Burgh.

78, Waterloo Bridge, London, S.
May 25th, 1870.

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THE CONDENSATION OF STEAM.

CHAPTER I.

INTRODUCTION.

THE PRACTICAL METHOD OF CONDENSING STEAM, IN STEAM ENGINES, BETWEEN THE YEARS 1705 AND 1838.

THE knowledge of the recoil of the atmosphere immediately after the explosion of gunpowder, doubtless originated the idea for the condensation of steam, from the fact that the sudden absence of a certain volume of air caused a vacuum, and that that vacancy was as suddenly filled with what surrounded it, and thus a second power was produced. It became evident also, that in any case if a vacuum could be caused mechanically, the surrounding vapour must fill its place, if permitted to do so, with an attendant force equal to the power required for the exhaustion.

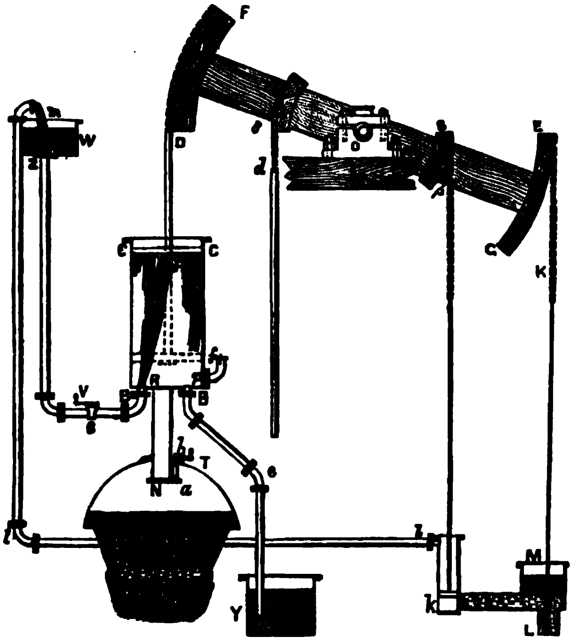
Now the fact of there being a vacuum was a grand discovery, only equalled by the use of steam in a practical form as a motive power, which began in the year 1688, at which period the condensation of steam commenced in a crude form.

Of course the men of science of that period were puzzled how to best adapt the power in their possession, and therefore after producing it, they began to condense it to cause a vacuum, by taking away the fire from the boiler, so as to allow the cooling action of the atmosphere to act on it wholly. This being a very slow process as well as laborious, the steam cylinder was put into another, so as to leave a space between them at the sides; and to condense the steam in the inner cylinder, the space was filled with cold water. An engineer named Newcomen was the inventor of that process in the year 1706, which is the date of the use of the first *surface condenser.*

Soon after this, or in the year 1711, Newcomen, with a Mr. Potter, made an engine to pump water from a mine, the engine being on Newcomen's condensing practice; but the pair were stricken with wonder to see, when they started their new engine, that it worked *double* as quick as they conjectured it would; and after an examination, it was discovered that the cold water in the outer cylinder passed, by a hole, into the inner cylinder, and thus the first *injection condenser* originated.

Newcomen, being elated at this circumstance, soon converted his old "surface" condensing engine into the then new

Fig. 1.



A copy of the original sketch of Newcomen's Single-Acting Land Beam Engine and Condensing Apparatus, invented and erected by him in the year 1711.

"injection" system, as illustrated by Fig. 1, in which A alludes to the boiler of a dome shape; and at a small height above it is a cylinder CBBC of metal; the boiler communicates with this cylinder by means of the steam-pipe N. The lower aperture of this pipe is shut by the plate N, which is ground very flat, so as to apply very accurately to the whole circumference of the orifice. The plate is called the regulator or steam-cock, and it turns horizontally round an axis *b a* which passes through the top of the boiler, and is fitted to the socket, like the key of a cock, by grinding. The upper end of this axis is furnished with a handle *b*T.

A piston P is suspended in this cylinder, and made air-tight by a packing of leather or soft rope, filled with tallow; and, for greater security, a small quantity of water is kept above the piston. The piston-rod PD is suspended by a chain, which is fixed to the upper extremity F of the arched head FD of the great lever or working beam FK, which turns on the gudgeon O. There is a similar arched head EG at the other end of the beam. To its upper extremity E is fixed a chain carrying the pump-rod KL, which raises the water from the mine. The load on this end of the beam is made to exceed considerably the weight of the piston P at the other extremity.

At some height above the top of the cylinder is a cistern W called the injection cistern, supplied by the pump K and the pipe *l l*. From this descends the injection-pipe ZSR, which enters the cylinder through its bottom, and terminates in a small hole R, or sometimes in a nozzle pierced with many smaller holes diverging from a centre in all directions. This pipe has, at S, a cock called the injection-cock, fitted with a handle V.

At the opposite side of the cylinder, a little above its bottom, there is a lateral pipe, turning upwards at the extremity, and there covered by a clack-valve *f*, called the snifting-valve, which has a little dish round it to hold water for keeping it air-tight.

There proceeds also from the bottom of the cylinder a pipe *p e g h*, of which the lower end is turned upwards, and is covered with a valve *h*. This part is immersed in a cistern of water Y, called the hot well, and the pipe itself is called the eduction-pipe; lastly, the boiler is furnished with a safety-valve. This valve is generally loaded with one or two pounds on a square inch; so that it allows the steam to escape when its elasticity is one-tenth greater than that of common air.

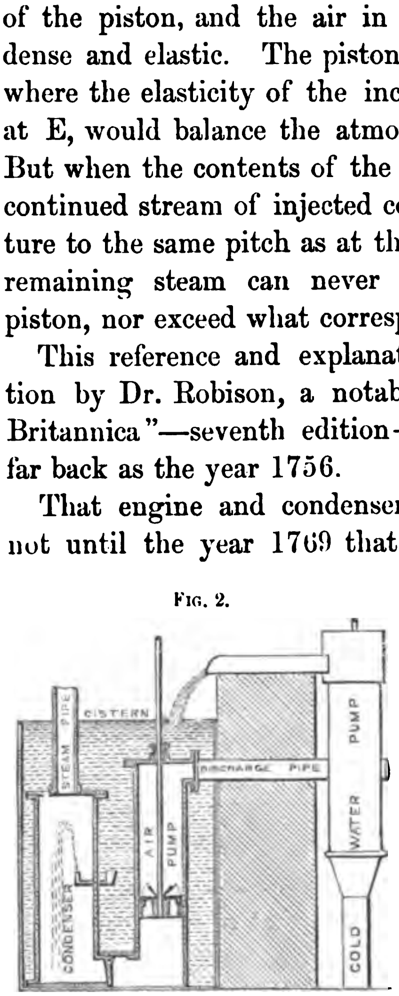
The water in the boiler being supposed to be in a state of strong ebullition, and the steam issuing by the safety-valve, let us consider the machine in a state of rest, having both the steam-cock and injection-cock shut. The resting position or attitude of the machine must be such as appears in the sketch, the pump-rods preponderating, and the great piston being drawn up to the top of the cylinder. Now open the steam-cock by turning the handle T of the regulator. The steam from the boiler will immediately rush in, and flying all over the cylinder, will mix with the air. Much of it will be condensed by the cold surface of the cylinder and piston, and the water produced from it will trickle down the sides, and run off by the eduction-pipe. This condensation and waste of steam will continue till the whole cylinder and piston are made as hot as boiling water. When this happens, the steam will begin to open the snifting-valve *f*, and issue through the pipe; slowly at first, and very cloudy, being mixed with much air. The blast at *f* will grow stronger by degrees, and more transparent, having already carried off the greatest part of the common air which filled the cylinder. We supposed that the water was boiling briskly, so that the steam was issuing by the safety-valve which is in the top of the boiler, and through every crevice. The opening of the steam-cock puts an end to this at once, and it has sometimes happened that the cold cylinder abstracts the steam from the boiler with such astonishing rapidity, that the pressure of the atmosphere has burst up the bottom of the boiler.

We may here mention an accident of which we were witnesses, which also shows the immense rapidity of the condensation. The boiler was in a frail shed at the side of the engine-house; a shoot of snow from the top of the house fell down and broke through the roof of the shed, and was scattered over the head of the boiler, which was of an oblong or oval shape. In an instant the sides of it were squeezed together by the pressure of the atmosphere.

When the manager of the engine perceives that not only the blast at the snifting-valve is strong and steady, but that the boiler is now fully supplied with steam of a proper strength, appearing by the renewal of the discharge at the safety-valve, he shuts the steam-cock, and opens the injection-cock S by turning its handle V. The pressure of the column of water in the injection-pipe ZS, immediately forces some water through the spout R. This coming in contact with the pure vapour which now fills the cylinder, condenses it, and thus makes a partial void, into which the more distant steam immediately expands, and by expanding rarefies. What remains in the cylinder no longer balances the atmospherical pressure on the surface of the water in the injection-cistern, and therefore the water spouts rapidly through the hole R, by the joint action of the column ZS, and the unbalanced pressure of the atmosphere; at the same time the snifting-valve *f*, and the eduction-valve *h*, are shut by the unbalanced pressure of the atmosphere. The velocity of the injection water must therefore rapidly increase, and the jet will dash against the bottom of the piston, and be scattered through the whole capacity of the cylinder. In a very short space of time, therefore, the condensation of the steam becomes universal, and the elasticity of what remains is almost nothing. The whole pressure of the atmosphere is exerted on the upper surface of the piston, while there is hardly any on its under side. Therefore, if the load on the outer end E of the working-beam be inferior to this pressure, it must yield to it. The piston P must descend, and the pump-piston L must ascend, bringing along with it the water of the mine; and the motion must continue till the great piston reaches the bottom of the cylinder; for it is not like the motion which would take place in a cylinder of air rarefied to the same degree. In this last case, the impelling force would be continually diminished, because the capacity of the cylinder is diminished by the descent of the piston, and the air in it is continually becoming more dense and elastic. The piston would stop at a certain height, where the elasticity of the included air, together with the load at E, would balance the atmospherical pressure on the piston. But when the contents of the cylinder are pure vapour, and the continued stream of injected cold water keeps down its temperature to the same pitch as at the beginning, the elasticity of the remaining steam can never increase by the descent of the piston, nor exceed what corresponds to this temperature.

This reference and explanation is according to the description by Dr. Robison, a notable writer for the "Encyclopædia Britannica"—seventh edition—also a great friend of Watt as far back as the year 1756.

FIG. 2.



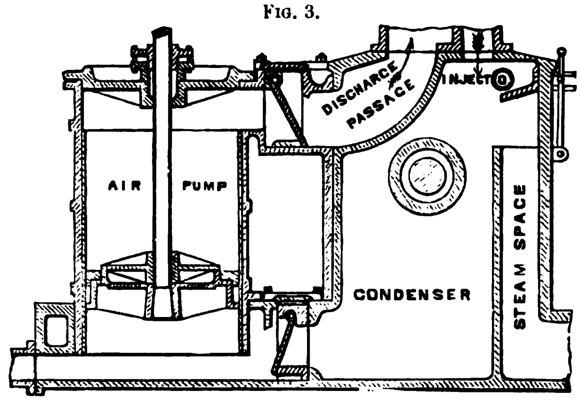
Sectional Elevation of Watt's Injection Condensing Apparatus, invented and erected by him for Double-Acting Land Beam Engines, in the year 1769.

That engine and condenser were single-acting, and it was not until the year 1769 that Watt introduced his condensing apparatus, as shown by Fig. 2, for double-acting land beam engines, which was arranged thus:—A large cistern of cold water was provided, and furnished continually with fresh supplies of cold water, either from a running stream or by means of the pump worked by the engine itself. In this is placed the condensing chamber, or condenser, wholly surrounded by the cold water, but perfectly empty, excepting that a small jet of cold water from the exterior is admitted through a regulated aperture to play in the inside. The steam-pipe conducts the steam out of the cylinder by the valve into the condenser, where it is reduced back into the water from which it had been originally generated. Now, it must be obvious on a little consideration, that the water which is injected into the condenser must rapidly accumulate there, becoming at the same time warmed by contact with the steam, so as to impede the process of condensation, and ultimately filling up the interior of the condensing chamber, which should be kept vacuous; and further, that the steam itself, becoming reconverted into water, would in a short period of time accumulate in the condenser and choke it up. Hence a principal and essential appendage of the condenser is a large pump, called the condenser-pump, or air-pump, which is essential to its long-continued efficient action, and which withdraws a portion of the accumulated warmed water from the interior of the condenser, and keeps it vacuous; and because there is generally air in combination with the water, and because also air is very apt to insinuate itself by many chinks or crevices into the condenser, this clearing-pump must be capable of pumping out air as well as water.

Watt is reputed to have introduced a "surface" condenser also, but instead of being as Newcomen's, it had a number of tubes or flat surfaces, through which the steam passed in the form of a vapour at one end and a fluid at the other, from the action of cold water surrounding the surfaces.

In the year 1820 steam navigation had been introduced nineteen years, and the side-lever engine—a copy of the land beam engine with inverted position for the beam—came into much use. The arrangements of the air-pump and condenser

Fig. 3.



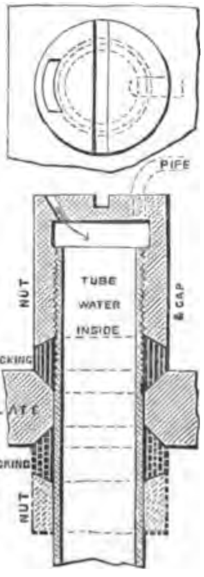
Sectional Elevation of Injection Condenser and Air Pump for a Side-Lever Marine Paddle-wheel Engine, as used in the year 1820.

are represented by Fig. 3 on the preceding page, which is a very near acquaintance of Fig. 2 on page 6, as far as the principles of the arrangements are concerned.

In this illustration—Fig. 3—the valves are metallic, and the steam from the engine cylinder enters at the top and bottom of the condenser, while the water discharge-passage forms a channel in the condenser, both being in one casting.

Our chronology now advances eleven years, and alludes to the invention of Mr. Samuel Hall's surface condenser, in the year 1831. This consisted of a series of tubes vertically secured in an iron casing of any convenient shape. Mr. Hall at that time entertained the idea that the steam should surround the tubes and the water pass through them, but not freely, but should rather be made to "fill and hold in" the tubes, instead of a free current passing as we now adopt. To accomplish that, each tube was fitted as shown by Fig. 4, which is a cap-nut enclosing the top, with an opening in the cap of a lesser area than the area of the tube, to admit the water therein; and the other end of the tube was fitted the same, but also with an inside nut as shown by dotted lines. The packing proposed was indiarubber and canvas, and the tube was "screwed" for a certain length at each end.

Fig. 4.

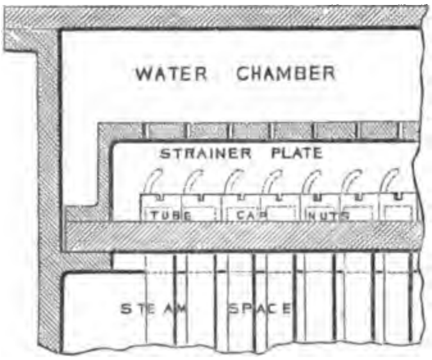


Hall's Tube Packing, invented in the year 1831.

Mr. Hall had also another feature in his invention, which was that the water entering the tubes should be "strained," to prevent any solid matter, as much as practicable, from entering and choking them, which arrangement is illustrated by Fig. 5, being an illustration of a portion of a condenser, with the tubes packed as explained, and covered by a perforated plate; but in some cases the plate was removed, and little curved pipes were used instead of the openings in the nuts, as shown in dotted lines in this view and in Fig. 4.

We cannot help remarking, that although Mr. Hall founded Surface Condensation, he carried it out, to begin with, in as bad a way as possible, by the adoption of the "perforated plate, the cap-nut, and the little curved pipe on it;" in fact, nothing could have been more fatal to his scheme, inasmuch that although he wanted the water to carry off the heat, he did all he could to prevent that operation.

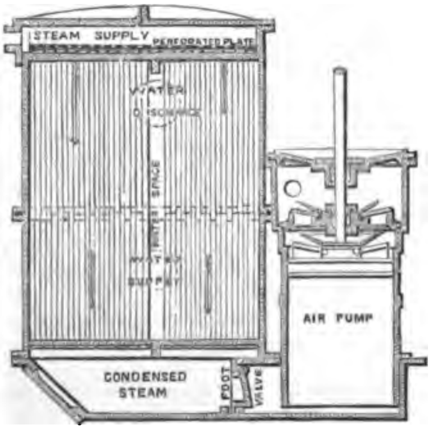
Fig. 5.



Hall's "Strainer," to prevent the choking of Condenser Water-tubes, invented in the year 1831.

As an evidence of this, nothing of any practical value was done until the year 1837, when the S.S. "Hercules" was fitted with a surface condenser having the steam inside the tubes, as

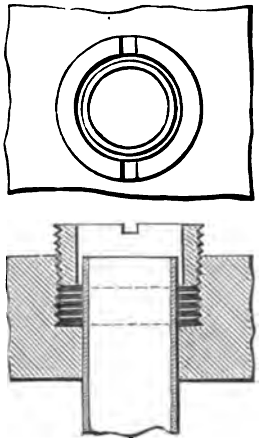
Fig. 6.



Hall's "Inside" Surface Condenser and Air-Pump, fitted in the S.S. "Hercules," in the year 1837, trading between London and Cork.

illustrated by Fig. 6, on the preceding page, and soon after H.M.S. "Megara" was fitted with one of a similar arrangement; but in both cases Hall discarded his "cap-nut and small pipe," and put in their place the sensible plan, as illustrated by Fig. 7, for packing the tubes. He still "held" to his perforated plate, however, but that soon gave way to a method for better distributing the steam as illustrated by Fig. 8, which is a series of thin curved plates, fixed on the tube plate at equal distances and at the main inlet, so that an equal area for the flow of the steam is ensured to an equivalent amount of tube openings. This was the best method then known, and finally led to the absence of that and all the preceding steam distributors, and in their place the free admission of the steam over the tube plate became generally adopted.

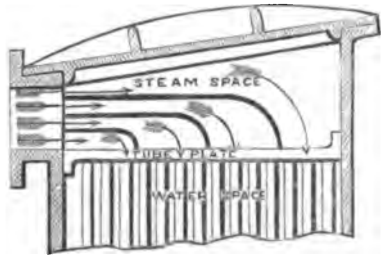
Fig. 7.



Hall's Tube Packing for Surface Condensers, applied in the year 1837.

From this date, 1838, the condensation of steam was very popular, and attention was next turned to reduce the size of the pumps, by making them double instead of single-acting, and the first of this kind is shown by Fig. 9. The action of the piston being "solid," duplicate valves are situated over and under the pump, and thus a continual suction and discharge is maintained during the up and down motion of the piston. The "working"

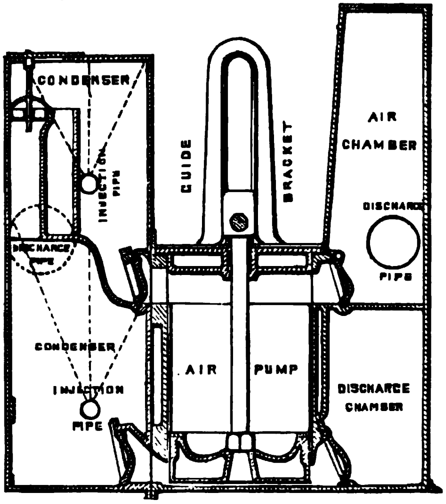
Fig. 8.



Hall's Method for the equal Distribution of the Steam for "Inside" Surface Condensation, applied in the year 1838.

of the valves is this:—On the piston rising the bottom left-hand valve opens, as also does the top right-hand valve, but the former admits water into the pump, and the latter permits the discharge from it: on the return stroke of the piston a reverse action of the other two valves occurs; it being understood that two valves are always stationary while the other two are in motion.

Fig. 9.



Sectional Elevation of the Double-Acting Air-Pump and Injection Condenser fitted in the Steamship "Nimrod" in the year 1843.

CHAPTER II.

MODERN INJECTION-CONDENSERS FOR LAND BEAM ENGINES, PRACTICALLY CONSIDERED.

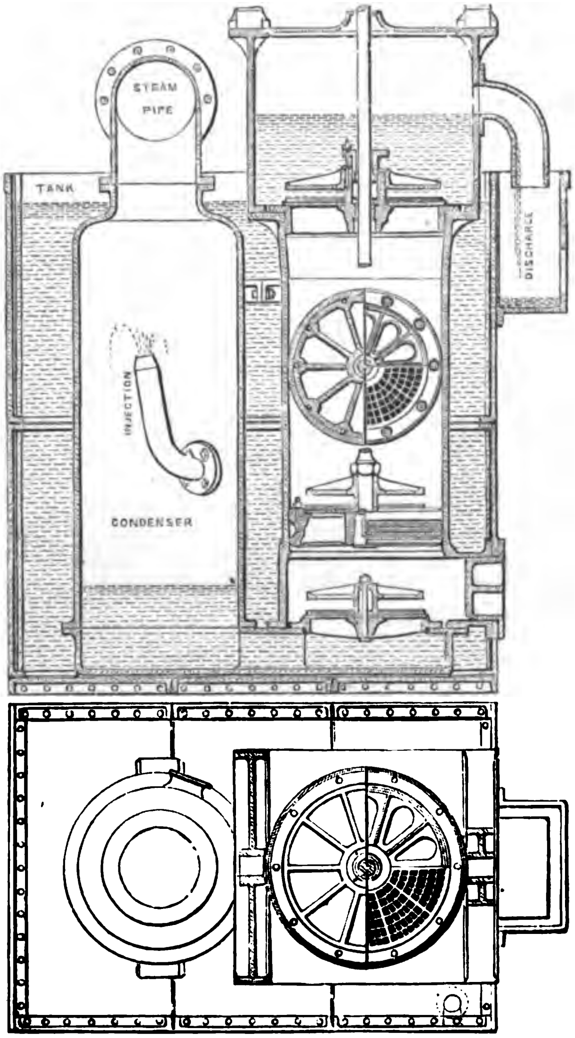
INJECTION CONDENSERS AND AIR-PUMPS FOR BEAM ENGINES.—When Watt arranged his condenser and air-pump, as shown by Fig. 2 on page 6, he "laid down" a rule which engineers copied for years after, without troubling themselves to inquire, or even think, whether it could be improved on or not. The matter before them was all-sufficient because it answered up to a certain point of working duty, and thus mutual contentment reigned where an equal desire for further knowledge should have been. The fact of this is clearly proven by the circumstance, of later makers of beam engines copying each other so close as those who immediately followed Watt copied him. As an illustration of this Fig. 10 is introduced, being a sectional elevation and plan of an air-pump and condenser by Mr. Howe of Chesterfield, for a pumping engine he erected at Clay Cross in the year 1862.

This is the best arrangement of the kind yet produced, because the "foot" or "suction" valve is directly at the end of the travel of the pump, but with the disadvantage of a considerable space between that valve and the piston when it is down, so that the condenser is never drained below the level of the bottom of the pump.

The condenser and pump are enclosed in a tank which is nearly full of water always, to prevent any escape of air should any of the joints leak below the water line.

In the year following, 1863, we designed a blowing beam engine for large Smelting works near London, and the condenser

FIG. 10.

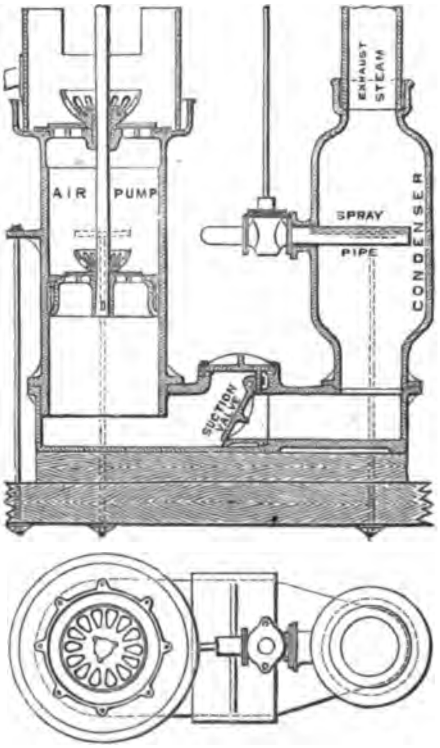


Howe's Arrangement of Air-Pump and Condenser of a Beam Engine erected at Clay Cross in the year 1862.

	ft.	in.		ft.	in.
Diameter of Steam Cylinder . .	7	0	Stroke of Pump. . . .	5	0
Stroke of Piston	10	0	Diameter of Injection Pipe .	0	6
Diameter of Pump	5	4	Area of Piston Valve . .	276·612 sq. in.	
Diameter of Rod	0	4	Area of Discharge Valve .	461·8 „	

and air-pump were arranged as shown by Fig. 11, being the general practice, as used in Cornwall especially. We put the suction-valve low down, and also the bottom of the pump, and thus obtained a vacuum of 26 inches constant. The entire casings were submerged in a water-tank made of cemented brick-work with a wooden floor.

FIG. 11.



Arrangement of the Air-Pump and Condenser of a Beam Engine erected at Weedon in the year 1863.

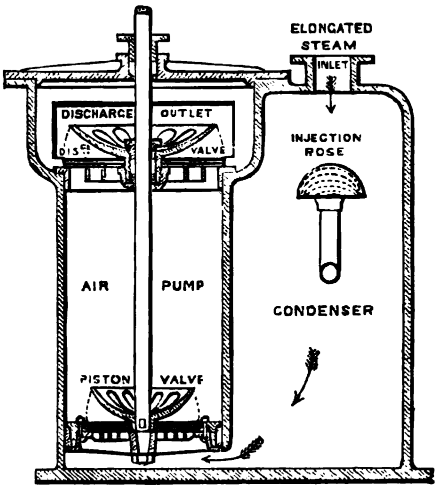
	ft.	in.		ft.	in.
Diameter of Steam Cylinder .	3	6	Stroke of Pump	3	3
Stroke of Piston	8	0	Diameter of Injection Pipe .	0	3
Diameter of Pump . . .	1	10	Area of Piston Valve . . .	160	sq. in.
Diameter of Rod	0	2½	Area of Discharge Valve . .	270	„

Cornwall may be termed the land of beam engines; in fact, they may be said to have been "raised" there more than in any other county. The engineers of that county being naturally ingenious, proved Watt to have been over-careful in providing a "foot" valve, to prevent the return of the water into the condenser, by omitting that valve, as shown by Fig. 12. This arrangement is the best of its class, on account of the piston valve being made to open freely, to admit the water into the pump on the descent of the piston. This has answered very well, and maintained as good a vacuum as the Watt arrangement does.

In two or three instances we have lately arranged the foot valve as shown by Fig. 13, where it is seen *inverted* in the bottom of the condenser, and the top discharge valve entirely removed. This has answered as well, and in many cases far better than the ordinary method, with a considerable saving by the absence of one valve seating and fittings, besides the lessening of friction. The level of the discharged water in this case was always below the top of the pump travel.

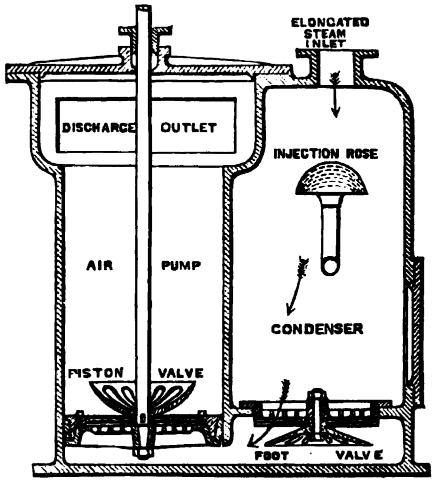
As far back as the year 1862 we introduced the overhead condenser, as illustrated by Fig. 14 on the next page, thus upsetting the former arrangements entirely. We introduced a plunger piston packed at the bottom end, and adjusted therefrom also. Two valves only were required at

Fig. 12.



Cornish Arrangement of Air-Pump and Condenser without a Suction or Foot Valve, used since the year 1858.

Fig. 13.

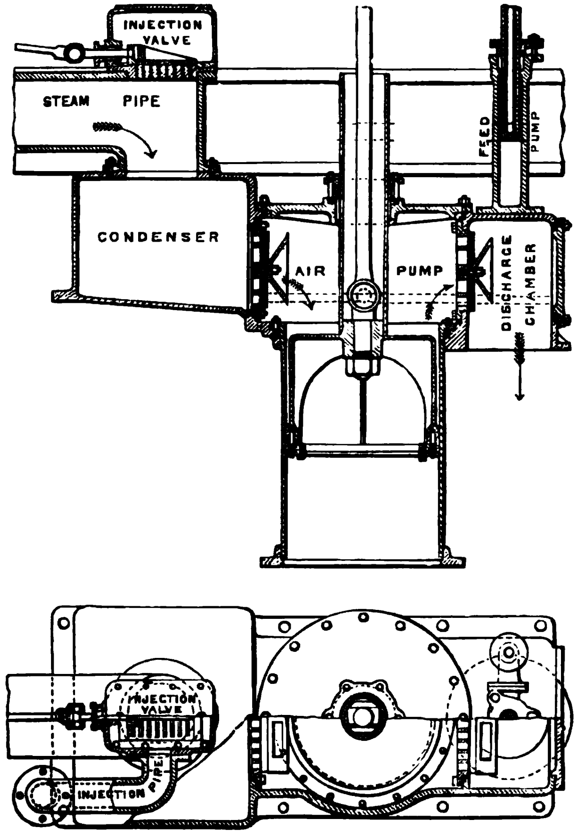


Burgh's Arrangement of Air-Pump and Condenser, with an inverted Suction Valve and no Discharge Valve, used since the year 1860.

the top of the pump, so that the water flowed nearly direct from the condenser to the discharge chamber.

The principle of the arrangement, as it occurred to us, was this: first, when the water that condenses the steam—and the steam condensed—must be *raised* out of the condenser, the density of that water must be a resistance against the piston at the down stroke, and the weight of the same a load to be lifted by it at the up stroke. Second, knowing from practical demon-

Fig. 14.

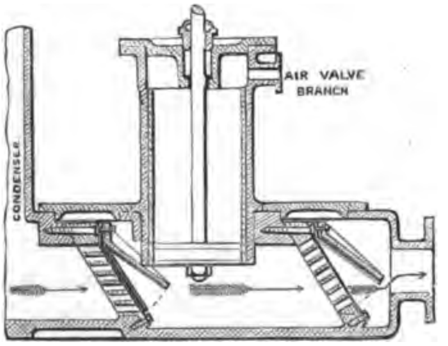


Burgh's "Over-head" Condenser and Air-Pump Arrangement for Beam Engines, applied in the year 1862.

	ft.	in.		ft.	in.
Diameter of Steam Cylinder	2	11½	Stroke of Pump	2	6
Stroke of Piston	6	0	Diameter of Injection Pipe	0	3
Diameter of Pump	1	10	Area of Suction Valve	150 sq. in.	
Diameter of Rod	0	2¼	Area of Discharge Valve	160 „	

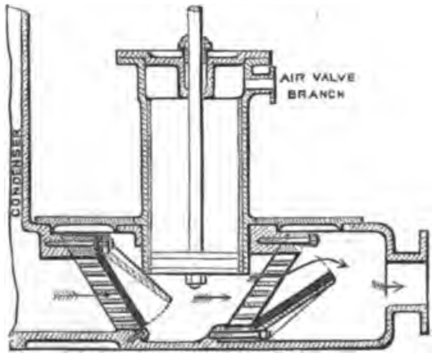
stration that *falling water produces a vacuum immediately around it*, we concluded that the injection water should *fall* on the steam, and that the contents of the condenser should *fall* into the pump, and there our theory ended; for we cared not much how the water was dispensed with afterwards, but nevertheless carried it off in the best way we knew. Well, the result was an extra *two* pounds of vacuum gained, over the old arrangements, with *half* the power to work the pump.

FIG. 15.



An Arrangement of Under-Valve Air-Pump, for the Condensers of Beam Engines, used since the year 1860, in America.

FIG. 16.

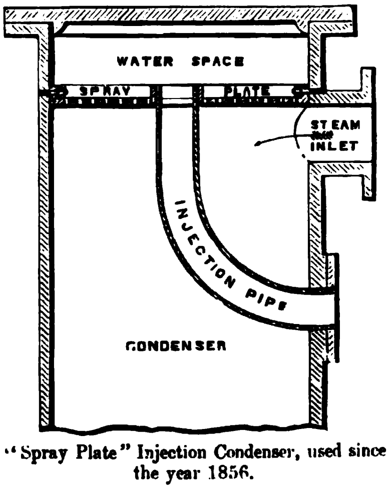


Burgh's Under-Valve Arrangement for Single-acting Air-Pumps for Steam Condensers, applied in the year 1863.

In another way this has been partially accomplished by putting both the valves *under* the pump, as shown by Fig. 15; but this arrangement could not, under any circumstance, accomplish as much as that preceding it, because some of the air *on* the water would remain in the passage between the valves, due to the reduction of the area of the discharge limit at the top; while by reversing the situation of the discharge valve a better effect could be ensured, as illustrated by Fig. 16 on the preceding page. Here it will be noticed that the discharge valve opens widest at the top, and thus a primary discharge of the air, followed by the water, occurs. The closing of the valve is occasioned by its elasticity, and the water pressing on it through the perforations in the guard.

It will be remembered that the examples of condensers we have hitherto noticed, excepting one, have the steam entering at the top and the injection pipe below, so that the water rises to meet the steam. A more efficient method is illustrated by Fig. 17, where the water pipe empties itself into a space at the top of the condenser, and the plate directly below being perforated, a "shower" of water falls to meet the steam as it enters the condenser directly under the plate, by which means a better vacuum is obtained than by the ordinary "rose" pipe.

Fig. 17.



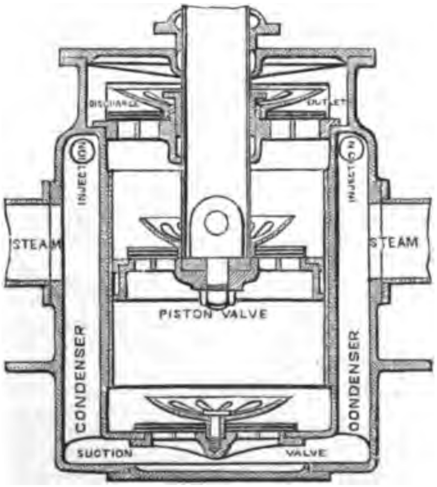
"Spray Plate" Injection Condenser, used since the year 1856.

CHAPTER III.

MODERN INJECTION CONDENSERS FOR OSCILLATING PADDLE-WHEEL MARINE ENGINES PRACTICALLY CONSIDERED.

Injection Condensers and Air-Pumps for Oscillating Paddle-wheel Engines.—The arrangement of the air-pump and condenser for this class of engine commenced about the year 1830, when Messrs. Penn and Son introduced them. As the engine power is comparatively small, the pump barrel and condenser are usually in one casting, as illustrated by Fig. 18. The three

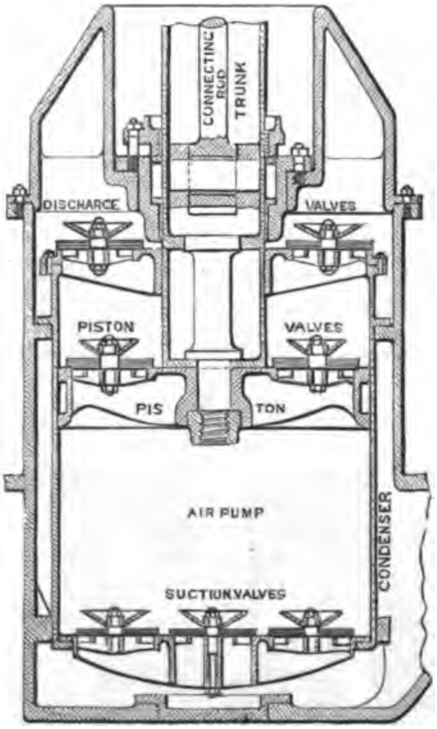
Fig. 18.



Modified Arrangement of Air-Pump and Annular Condenser for Vertical Oscillating Paddle-Wheel Engines, as generally fitted in small river steamers since the year 1830.

valves for "suction, lift, and discharge," are directly over each other, so that the former can only be inspected by the removal of the two latter. The condenser shell surrounds the pump barrel, and the annular space is the condenser proper, the injection water entering sometimes below the steam openings, rather than above, as illustrated.

FIG. 19.

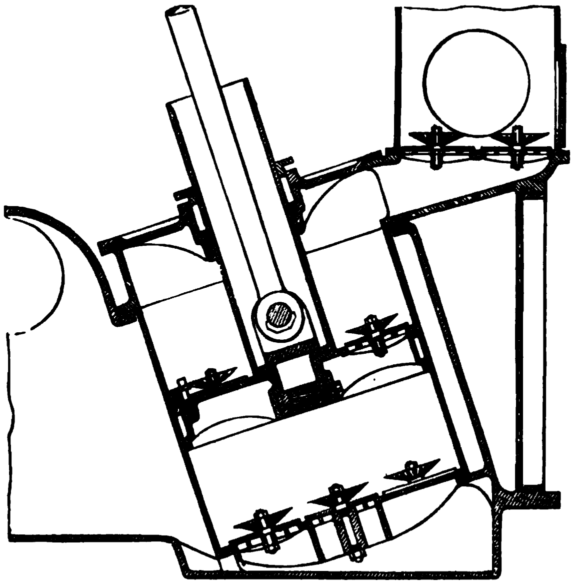


Laird's Trunk Air-Pump and Side Condenser for Angular Oscillating Paddle-Wheel Engines.

	ft.	in.			
Diameter of Steam Cylinder	3	5½	Number of Suction Valves	7	
Stroke of Piston	4	6	Total area of Suction Valves	187	sq. in.
Diameter of Air-Pump	2	4¾	Number of Piston Valves	7	
Depth of Piston	0	5½	Total area of Piston Valves	187	sq. in.
Diameter of Trunk	0	9½	Number of Discharge Valves	8	
Stroke of Piston	1	9	Total area of Discharge Valves	212	sq. in.
Diameter of Connecting Rod	0	3	Diameter of Injection Pipe	3¾	in.

Of a general character for larger engines is the arrangement shown by Fig. 19, in which the valves are multiple, and the connection of the trunk with the piston separate from the guards. The condenser is also at the side, instead of being a portion of the barrel; in fact, the entire mechanical connections require, from their size, to be as illustrated, rather than as in the preceding example. This arrangement is used for angular oscillating engines chiefly, where the two connecting, or piston, rods, are attached to the same crank-pin, and the pumps and condensers at the *ends* of the engines instead of between them, which, when occurring, the pumps are angularly situated, as shown by Fig. 20, and the engine cylinders vertical, when their pistons are at half stroke, or what is termed the "vertical oscillating engines."

Fig. 20.



Present Arrangement of Air-Pump and Condenser for large power Vertical Oscillating Paddle-Wheel Engines, used since the year 1862 by the leading firms of England and Scotland.

	ft.	in.
Nominal H.P. of Engine, 250		
Diameter of Connecting Rod .	0	3
Diameter of Air-Pump . .	2	10
Diameter of Trunk . . .	0	10½
Length of Stroke	1	9

Area of Foot Valves (7 for 1 pump)	276 sq. in.
Area of Piston Valves (7 for 1 pump)	241·5 sq. in.
Area of Discharge Valve (8 for 1 pump)	276 sq. in.

Diameter of Injection Pipe (2) 5 inches.

This is a very neat arrangement, and is now universally used by Messrs. Penn, Maudslay, Ravenhill, Napier, and Rennie.

Each portion, it is seen, is separate, instead of some parts being combined: this is for the better processes of moulding and fitting, as in the event of a disaster with any part, it affects that only; while at the same time with large sizes the pattern is practically too cumbersome for one entire casting.

Of course it will be noticed that only one half of the arrangement is shown in the illustration, but both being duplicates the completion is readily understood.

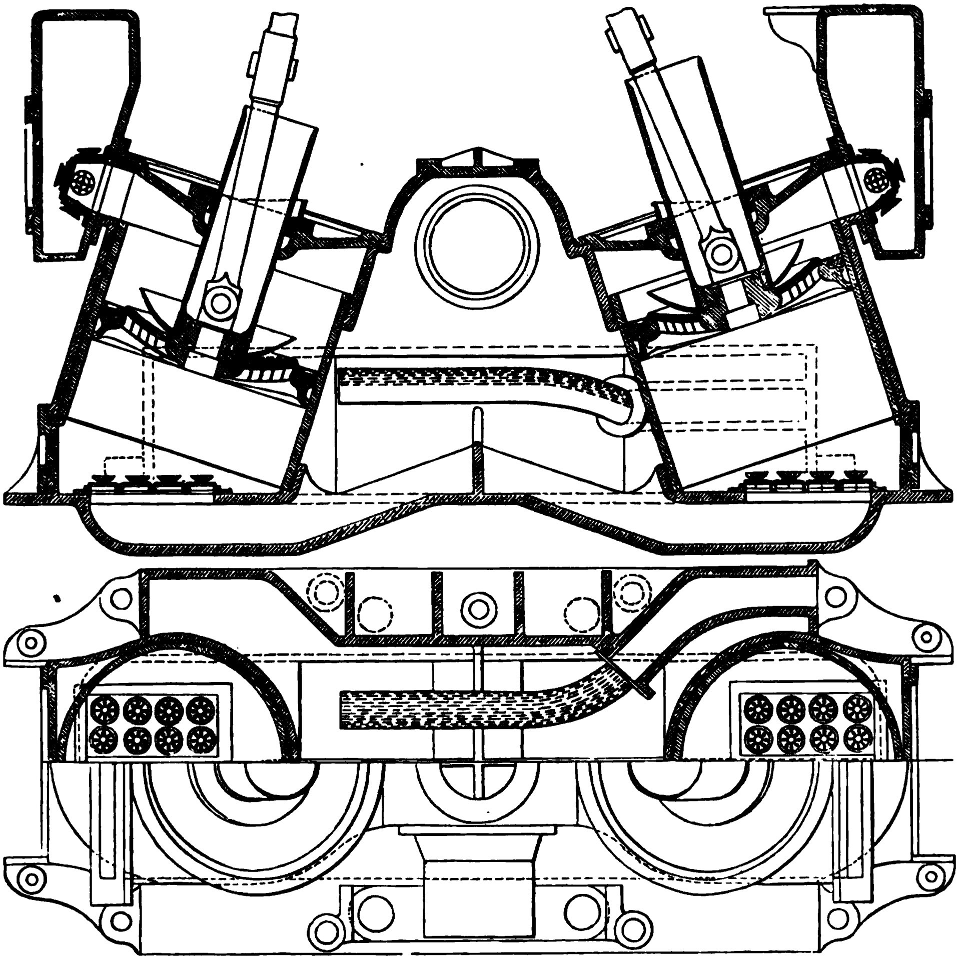
The next example—Fig. 21—is by the well-known firm of Messrs. James Watt & Co., it being for the same purposes as that just described: the illustrations are in sectional elevation and plan, and show the details very clearly. In the place of small valves on the piston, Messrs. Watt prefer one valve with a curved seating, to lend "help" to the action of the valve as it closes. The arrangement of the suction valves is very good, because a door is provided to inspect, refit, or remove them, which are matters of the greatest importance at sea, and only to be appreciated by those who practically have used the advantage, and in other cases have not had the means to do so.

Another worthy feature is the discharge valve seating, it being a box fastened to the side of the chamber, perforated at suitable places as valve openings, and on them the valves and guards are secured as ordinarily. The gain here is that those valves are at the top, bottom, ends, and front of a box, thus occupying much less room in length and breadth than the flat plate arrangement. All the remaining portions being similar as those described, also being self-explanatory, we proceed to notice an arrangement by the late John Elder, as illustrated by Fig. 22.

Although this dates back to the year 1856, it is an evidence that the requisite improvements were considered then as much as in later times, as shown on page 24.

Mr. Elder, with his partner Mr. Randolph, patented a species of direct-acting angular engines, high and low pressure combined, and with that and other matters, the pump arrangement under notice, which consisted of being double-acting, with duplicate valves on each side of the barrel, and the piston worked vertically under any circumstance of use.

Fig. 21.



Watt's present arrangement of Air-Pumps and Condenser for Oscillating Paddle-Wheel Engines, used by them, since the year 1860, for all classes and powers.

	ft.	in.
Nominal H.P. of Engines, 300		
Diameter of Connecting Rod	0	4½
Diameter of Air-Pump	3	4
Diameter of Trunk	0	13
Length of Stroke	2	6

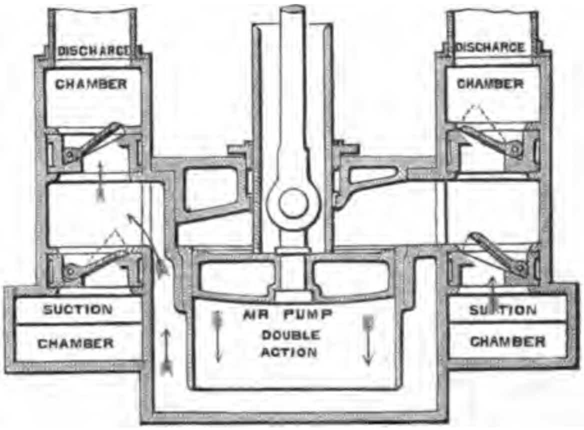
Total area of Foot Valves (one pump)	338 sq. in.
Total area of Piston Valve (one pump)	351·68 sq. in.
Total area of Discharge Valves (one pump)	378 sq. in.

Diameter of Injection Pipe 6 inches.

The main attainment is, that as the suction valves are at the top of the pump, and those for the discharge immediately above them also, the piston acting as a "plunger" instead of a "bucket," the water therefore "falls" into the barrel and thus a "syphon" action is produced.

Treating next of general matters relating to pumps, it must be noticed that Penn, Maudslay, and Ravenhill have sometimes put the discharge valve directly over the air-pump piston, allowing the trunk to pass through the top valve seating, and studs or bolts passing through the top cover retain the seating in question in its position. This, although objectionable as an arrangement theoretically, is not found practically inconvenient, as the entire portion above the foot valves, with small engines below 50 horse power nominal collectively, can be removed without a separate disconnection.

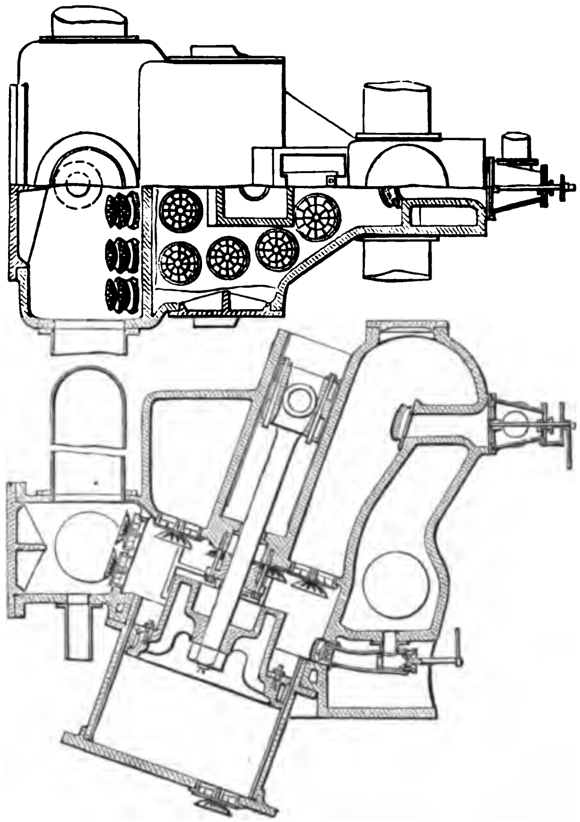
Fig. 22.



Elder's Double-Acting Air-Pump for Condensers of Paddle-wheel Engines, patented in the year 1856.

Notwithstanding these facts relating to small engines, and that doors are arranged to admit access to the "foot valves" in larger examples, it is obvious that in either case an *independent* means of access to the separate portions is not available. Another question also presents itself for due attention—*the position of the condenser relative to the air-pump.* It is seen that the general practice, from the examples previously noticed, is to arrange the condenser and pump on the same level in principle, and thus the water will not rise in the pump—by gravitation—above that in the condenser. The drainage of the condenser is only admitted by the rising of the air-pump piston, and should the latter not be in perfect order, a great loss of vacuum is the result. The main cause for the universal adoption of the arrangements in question, combined with the knowledge of their several defects, is that the motion imparted to the pistons is from the crank shaft, and thus an almost vertical action imperative. The condenser also, with large engines of great weight, must, or should be, as low in the hull of the vessel as practicable. The pumps are, as a rule, with little exception, single acting, and thus the foot valves are at the bottom of the condenser, at the base of the pump; the recessed portion, directly below the barrel, admitting an accumulation of the condensed steam and water under the valves in question. On the piston *rising*, the foot valves *open*; the water leaves the condenser and *ascends* in the pump, although the *natural* course of the fluid is to *descend*. The piston, when descending, closes the foot valves by causing a load on them, due to the water in the pump; the weight is next relieved from the valves by the rising of the piston, and the final discharge effected. Now the action of the piston and valves as arranged in the examples alluded to being obvious by noticing the illustrations, the description just presented may seem unnecessary; it must be added, however, as a cause, that although the remarks in question are in connection with the prior examples, they refer comparatively to the arrangement next to be alluded to, represented by Fig. 23 on the next page. In this example the condenser is *above* the pump, the bottom of the former being nearly level with the exhaust opening in the trunnion. The *suction valves* are *inverted*, and the *discharge valves* laterally situated directly *below* the former. The piston is of a peculiar section, recessed to suit the requirements of adjustment, and effecting an almost perfect discharge from the space directly under the condenser. The piston rod passes through the bottom of the condenser, in which latter compartment a guide channel is formed. The discharge chamber and air vessel are of the ordinary kind, with the feed water pipe shown connected to the underside. The injection valve passage and rose-pipe are near the roof of the condenser, a certain height above the trunnion openings. The cock and valve below the trunnion openings are for the purpose of permitting a discharge of any

Fig. 23.



Burgh's Over-head Condenser, Plunger Air-Pump, requiring only *two* sets of Valves, with perfect condensation, for Oscillating Paddle-wheel Engines, invented in the year 1862.

	ft.	in.		ft.	in.
Nominal H.P. of Engine, 150			Length of Stroke	2	0
Diameter of Connecting and Piston Rods	0	4	Area of Suction Valves (10) .	260 sq. in.	
			Area of Discharge Valves (12)	280 sq. in.	
Diameter of Air-Pump . . .	2	10	Diameter of Injection Pipe. .	4⅜ in.	

condensed steam that may accumulate in the exhaust steam passage at the front of the condenser.

The sectional elevation having been thus far alluded to attention must now be directed to the plan. To render this view practical as well as conclusive, one half is shown in section and the other complete.

This arrangement of condenser is especially adapted to admit ample space for adjusting and renewing the adjustment and packing of the exhaust trunnion stuffing boxes, an advantage only to be appreciated by those who are acquainted with the cramped space generally allotted for those purposes. Access to the entire set of valves is attained by doors suitably placed, the representation of which is seen in both views.

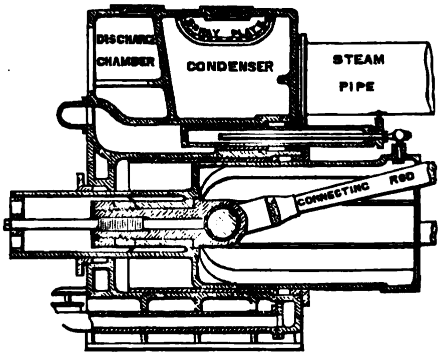
Next to be considered is the *actual* gain by the adoption of the arrangement under present notice over those previously alluded to as the common practice. It will be remembered it has been stated that, with the usual arrangements, "on the piston *rising* the foot valves *open*." Now in the present case matters are reversed, the valves, common to the condenser, *open* only to drain the same, when the piston is *descending;* after this is accomplished the water is discharged without passing *through* the piston; thus finally the same result ensues, the water is discharged when the piston is ascending—as before—but the foot valves are *closed.* Further than this, as an actual gain, the *gravity* of the water assists the action of the pump when draining the condenser. By this arrangement a better vacuum is certain, and *one entire set of piston valves* dispensed with. Economy of material is thus produced, simplicity of arrangement effected, and the main attainment—"perfect condensation"—rendered certain.

CHAPTER IV.

INJECTION CONDENSERS FOR HORIZONTAL MARINE SCREW-PROPELLER-ENGINES PRACTICALLY CONSIDERED.

Trunk Air-Pump Plungers and Condensers for Screw Engines.—When Messrs. Penn and Son patented their improvement on the trunk engine invented by Mr. Humphrys—who would use oval trunks instead of those of a circular shape—several marine engineering firms agitated the question of evading Messrs. Penn's patent, but, if possible, retaining the main advantages at the same time. Now to put the double cylindrical trunks in the engine cylinder was Messrs. Penn's claim, and not to do that was what was required. First Messrs. Napier and Son of Glasgow came forward with their ideas to accomplish it about twenty years ago similar, as illustrated by Fig. 24, which is an improved arrangement dating back about

Fig. 24.

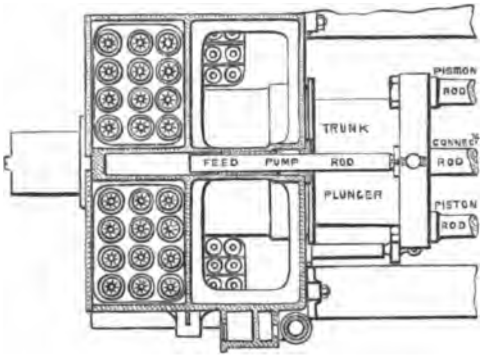


Longitudinal Sectional Elevation of Napier's Plunger Trunk Air-Pump and Condenser, invented in the year 1850.

half that time. The sectional plan is shown by Fig. 25, and the complete end and sectional elevations by Fig. 26.

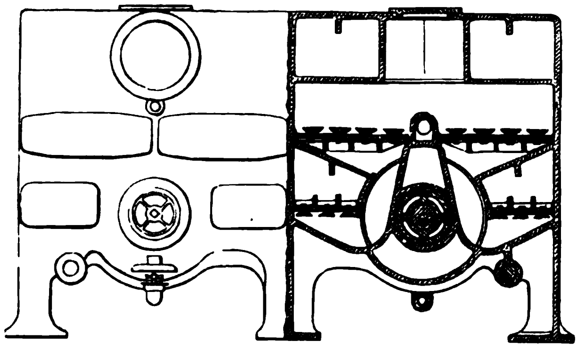
Messrs. Penn, it will be remembered, put the trunk and connecting rod in the steam cylinder, but Messrs. Napier, to escape that, put those details in the condenser, and thus made the trunk a single-acting plunger pump, worked by two piston rods from the steam piston. The condenser is arranged partially

Fig. 25.



Sectional Plan of Napier's Plunger-Trunk Air-Pump and Condenser, invented in the year 1850.

Fig. 26.



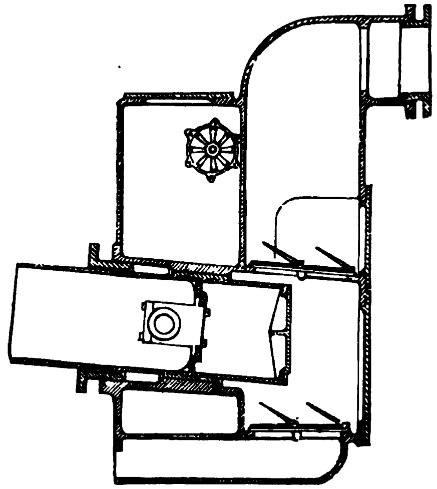
Complete and Sectional Elevations of Napier's Plunger Air-Pump and Condenser, invented in the year 1850.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 900			Diameter of Suction Valves .	0	6½
Diameter of Trunks (2) . .	3	7	Number of ditto (42)		
Diameter of Guiding or Adjusting Tube	1	6¾	Diameter of Discharge Valves .	0	9⅛
			Number of ditto (24)		
Length of Stroke	4	0	Diameter of Injection Pipe . .	0	7½
Diameter of Connecting Rod .	0	8¼	Diameter of Discharge Pipe . .	2	1

over the pump and at the sides; the suction valves are inverted, and directly over them are those for the discharge, their chamber being at the back over the pump. This requires a complicated casting, but nevertheless is very ingenious, and clearly illustrates what one inventor will do to evade the ideas of another.

The mode of adjusting the brasses in the eye-piece of the connecting pin is very ingenious but expensive: it requires a guide portion or small trunk at the back end of the larger, in which is an adjusting screw-rod and loose set-rod, with jam-nuts to keep the eye-piece in its place, to resist the "pull" and "thrust" imposed on it. We may add that Messrs. Napier are obliged to make the diameter of the plunger pump large enough to allow the connecting rod to clear within it, rather than adopt the usual proportions.

FIG. 27.



Rennie's Plunger Air-Pump and Condenser, invented in the year 1855.

Nominal H.P. of Engines, 200

	ft.	in.		ft.	in.
Diameter of Pumps (2) . . .	1	6	Number of Suction Valves (6)		
Length of Stroke	2	0	Number of Discharge Valves (6)		
Diameter of Connecting Rod .	0	3	Diameter of Injection Pipes (2) .	0	3¼
Sizes of Valves (7 × 12 in.)			Diameter of Discharge Pipes (2)	1	0

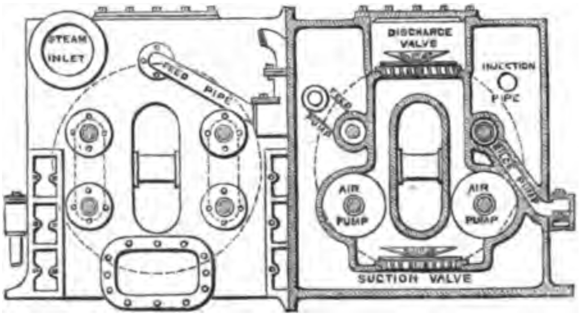
Five years after Messrs. Napier began, or about sixteen years ago, Messrs. Rennie "followed suit," and they had not only Messrs. Penn's plan to evade, but also the Napiers'. To accomplish the first, a single trunk was used, and to do the second, the piston rods were removed and a connecting rod applied in their place. This feat of ingenuity produced the condenser as shown by Fig. 27.

The plunger is a hollow tube, with a closed end, forming a separate portion, secured by bolts and nuts. The connecting pin of the connecting rod is secured, about two-thirds of the length of the plunger, by bolts and nuts to flanges cast with the same, so that when the plunger is at half-stroke—as shown—the centre of the pin is at the centre of the guiding and packing portions forming the stuffing box. The condensing chamber is at the front end of the structure. The injection valve—seen near the top—is a perforated disc, acting on a seating of similar design. The exhaust steam enters the condenser opposite the injection valve, and thus an immediate contact of the steam and water is the result. The door above the valve permits inspection and access for repairs. The pump being single acting, the valves are at the extreme end of the barrel, over and under the same. These valves are rectangular in plan, and the seatings perforated like the honeycomb, rather than square or round passages. The guards are flat perforated plates, at the requisite angle, in proportion to the lift sufficient for the valves. The doors for the inspection, renewal, &c., are at the back of the discharge chamber. This latter compartment is over, and partly around, the barrel. The discharge opening is above the roof of the condenser, rather than level with it, as in many instances.

The snifting valve, in the section under notice, is at the front of the condenser, while in other examples the back of the same is considered the preferable position; certainly the latter position is the more accessible.

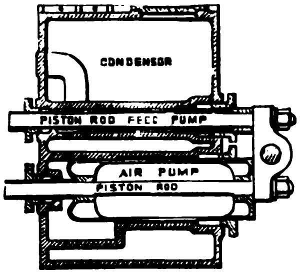
No sooner had Messrs. Rennie brought their arrangement into frequent use in their practice, than Mr. Tod, of Glasgow, introduced his, as illustrated by Fig. 28, which is sectional and complete elevations of the condenser and pumps. Fig. 29 is a longitudinal sectional elevation, and Fig. 30 a sectional elevation, showing the pump in complete view. The air-pumps are disposed within the condensers, and in the same horizontal plane with the main steam cylinders, and they balance the latter on the opposite side of the keel line. Each main steam piston is fitted with four piston rods, disposed in a parallelogram, and working through stuffing boxes in the front covers, or on the end of the cylinders next the keel, so that there are in each an upper and a lower pair of rods. Those piston rods are cottered by end connections to other and corresponding rods which pass through stuffing boxes in the front end of the condensers next the keel, and of course immediately opposite the stuffing boxes of the steam cylinders, two being above and two below the main cranked or engine shaft. All the rods pass directly

Fig. 28.



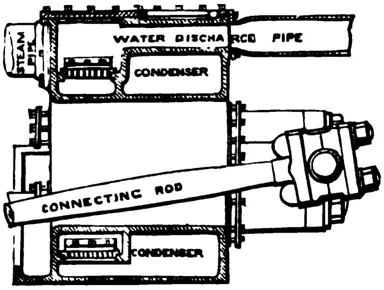
Complete and Sectional Elevations of Tod's Twin-Plunger Air-Pumps and Condenser, patented in the year 1859.

Fig 29.



Longitudinal Sectional Elevation of Tod's Twin-Plunger Air-Pumps and Condenser, patented in the year 1859.

Fig. 30.



Sectional Elevation of Tod's Condenser, showing the Pumps in complete view, patented in the year 1859.

through the condenser, on the outside of which, next the side of the vessel, they are connected together to work thus by a suitable horizontal crosshead with transverse end pieces. To the centre of each crosshead there is jointed the external end of a horizontal connecting rod, which passes back transversely through a transverse vertical slot in the condenser to a twin-crank pin on the main shaft. Obviously then, whilst the pistons and rods are well guided, long connecting rods are obtained, and the effect of the transverse reciprocatory action of the pistons is transferred to the main shaft. The piston rods are applied also for working the air-pumps and the feed and bilge or other pumps necessary for the action of the engines, or for the requisite working of the ship when afloat.

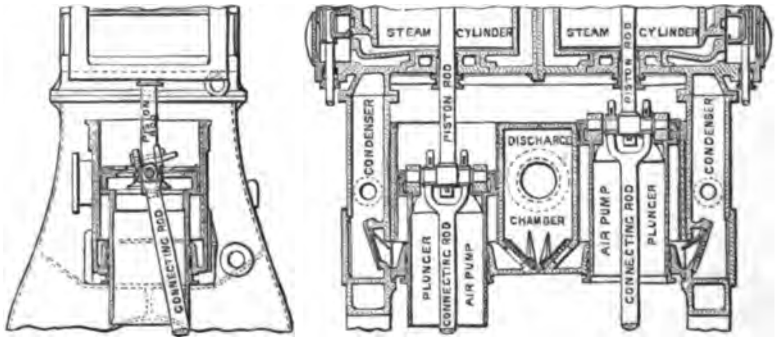
As each engine steam cylinder has a pair of air-pumps opposite to it, that are situated in the condenser, and as the lower pair of piston rods in each case actuate those pumps, and that the piston rods each pass through a hollow or tubular brass or gun metal plunger turned to fit the corresponding air-pump, and are connected to the plunger by a collar and nut at the external, crosshead, end; evidently the air-pumps, as there are two to each steam cylinder, may have comparatively small diameters, while they have the same stroke as the steam cylinders.

The air-pump plungers work through stuffing boxes in the outer sides of the condenser, and thus form a good guide for the steam piston rods. Each condenser surrounds or envelopes its corresponding air-pumps, which are situated in the lower part thereof, and the two in each case have one common intermediate suction or foot valve for taking the water and vapour from the lower part of the condenser, while a similar common valve above affords the means of discharge to the hot well and elsewhere. The upper pair of elongated steam piston rods in each case works the feed and bilge pumps of the vessel, the respective plungers being directly attached to the rods as in the case of the air-pumps, and an equally good guide is thus secured. The two condensers are bolted together, and to the framing in the same manner, as the steam cylinders.

Four years from the last date, or in the year 1863, Mr. Jackson, of the Canal Iron Works,—Seaward's old works,—patented and made the arrangement shown by Fig. 31.

Instead of employing a guide block and guides, or any of the usual methods for guiding and supporting the outer end of the piston rod at its junction with the connecting rod, and instead also of working a pump by a lever, or from off the crank, or by an eccentric, or other means of communicating motion, those two means for guiding the piston rod and working the pump are effected by placing the pump barrel with its longitudinal position in or nearly in a line with the cylinder, between the cylinder and the crank shaft. The pump plunger or piston is connected to the engine piston rod, and also to the end of the connecting rod of the crank-pin, by a pin, and the connecting rod being forked, thus the pump is worked direct, and forms also the guide for the piston rod.

Fig. 31.

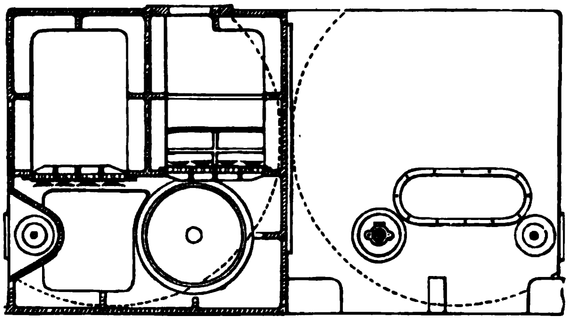


Jackson's Air-Pump Plunger and Condenser, as patented and fitted by them for Inverted Screw Engines, in the year 1863.

For injection condensing engines the air-pump is the pump employed in this manner, and its piston or plunger is of sufficient diameter to allow of a trunk large enough to permit of the connecting rod vibrating therein; and where the distance between the cylinder end and the crank shaft is limited, as is generally the case in horizontal marine screw engines, it is preferred to employ a single-acting and single trunk pump, the capacity of the pump chamber or barrel being regulated by the dimensions of the annular space, or the difference between the exterior diameter of the trunk and the interior diameter of the pump barrel.

In inverted direct-acting screw engines the valves may be placed at the bottom of each pump in direct communication with the condenser, as illustrated. In every case the connecting rod works within the trunk of a pump placed between the cylinder and the crank, and the cylinder of the pump and the packed end or ends thereof, or the piston and the gland alone are the means of guiding the piston rod, and of taking the thrust due to the angular motion of the connecting rod.

Fig. 32.



Penns' Injection Condensers and Double-Action Air-Pumps, for directing Double-Trunk Screw Engines, as used since the year 1860.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 1350			One set of Suction Valves (24)		
Diameter of Pumps (2) . .	2	10	Diameter of Discharge ditto .	0	8½
Length of Stroke	4	4	One set of ditto (24)		
Diameter of Pump Rod . .	0	4¾	Diameter of Injection Pipes (2).	0	9
Diameter of Suction Valves .	0	8½	Diameter of Discharge Pipes (2)	2	0

Condensers and Air-Pumps for Direct-Acting Screw Engines.—The type of condenser now under notice is the ordinary kind, fitted with double-acting air-pumps, and in the place of a plunger, a piston is used, and a rod connects the same to that in the cylinder.

With this arrangement of engine, or direct acting, every facility is available to arrange the condenser pumps and valves as compact as practicable, and this advantage is well represented by the following examples.

Messrs. J. Penn and Son arrange the valves and pumps as illustrated by Fig. 32, on the preceding page. The condensing and discharge chambers are *above* the periphery of the pump. The suction valves are *inverted* at the side of the barrel, and those for the discharge are directly above, with upward action. The barrel is a tube cast midway of the length; each set of valves are arranged to drain and discharge simultaneously—or when the front end set is draining the condenser, those at the opposite extremity are permitting the final discharge. The arrangement under notice is in duplicate portions, thus rendering each condenser, pump, and set of valves common only to the opposite engine. There are two practical advantages resulting from this; first, a saving of patterns, and secondly, portability for erection. Further than this, another gain is effected, *i.e.*, in the event of either engine being disabled, the one at work is not subject to both condensers, sets of valves, &c.

A longitudinal section of the arrangement will show the valves arranged the entire length of the condenser, in sets of four and two rows, on each side of the central rib, supporting the barrel; and this in principle relates also to the succeeding examples, where the valves occupy the length of the condenser.

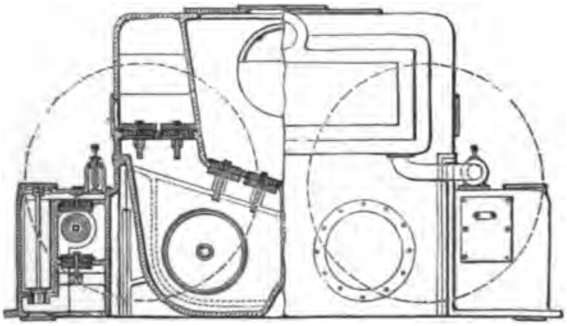
The exhaust steam enters each condenser at the top, or on the roof of the condensing chamber. The injection water is introduced at the side—fore and aft—directly below the roof, therefore an instantaneous effect is ensured. The discharge opening is nearly level with the bottom of the chamber over the pump. The doors for access to the suction valves are at the back and front of the chamber below the same; those for the discharge valves are on the roof, near the central side or connection of the structure.

Following next as the originators of well-arranged air-pumps and condensers are the well-known firm of Messrs. Humphrys and Tennant. They, unlike Messrs. Penn, prefer one condensing chamber common to both cylinders, as shown by Fig. 33. The discharge chambers are on each side of the condenser, and both are sufficiently high above the pumps to enable a free passage for the water. At the back end of the condenser the discharge chambers are connected by passages, and thus *one* discharge pipe only is requisite. The suction valves are inverted in the bottom of the condenser at an angle; and the discharge valves, with a reverse action, are secured in the bottom of the discharge chambers.

The valves are the flat kind, almost square in plan—the seating being perforated in the ordinary manner. The guards are twin-angular, and thus the valve rises and falls on each *side* of its connection.

The exhaust steam enters the condenser at the front end, below the roof, and the injection water directly opposite. The doors for access to the valves are at the sides and top of the respective chambers.

FIG. 33



Humphrys' Injection Condenser and Double-Acting Air-Pumps, for Single Piston Rod Direct-Acting Screw Engines, used since the year 1859.

Nominal H.P. of Engines, 400

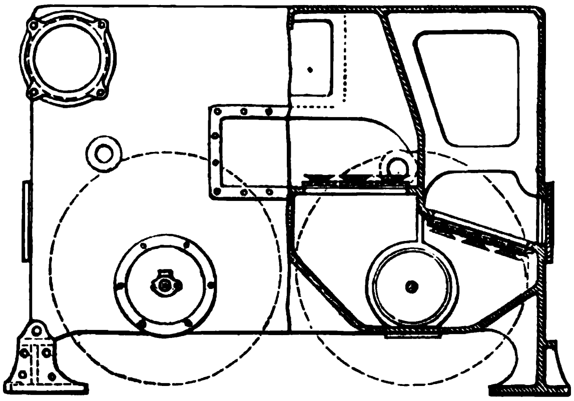
	ft.	in.		ft.	in.
Diameter of Pumps (2) . .	1	10	One set of Suction Valves (12)		
Length of Stroke	3	0	One set of Discharge ditto (12)		
Diameter of Pump Rod . .	0	$2\frac{3}{4}$	Diameter of Injection Pipe . .	0	8
Size of Valve . 9+7 inches			Diameter of Discharge Pipe . .	2	0

The arrangement next worthy of notice is that by Messrs. J. and W. Dudgeon, represented by Fig. 34, on the next page. The central compartment is the discharge chamber—common to both pumps —and the condensers are on each side of the same. The suction valves, of the disc kind, are inverted at an angle, as in the previous example, also the position of the discharge valves are similar. The exhaust steam enters the front of the condenser below the roof, and the injection water flows in at the sides, to render a vacuum certain.

The doors, for internal access to the suction and discharge valves, are at the front, back, and sides of the chambers. The discharge opening is at the back end, and directly below the roof, instead of the base of the chamber.

If not in design, certainly in arrangement, the illustration depicted by Fig. 35 forms a striking similarity to that of Fig. 33. The situation of the condenser is the same, also the discharge chamber, but the injection water is admitted at the sides—at the back end, rather than a central position. Both discharge chambers are connected at the back ends by a passage, and the discharge pipe is connected to the central opening.

FIG. 34.

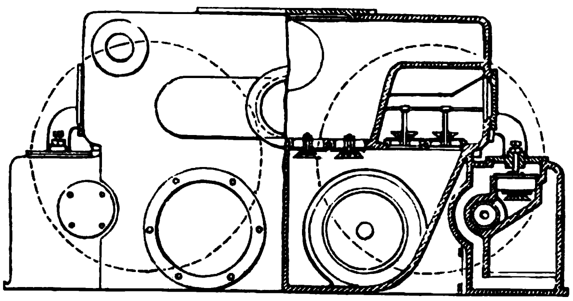


Dudgeon's Injection Condensers and Double-Acting Air-Pumps, for Single Piston Rod Direct-Acting Screw Engines, used since the year 1864.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 150			One set of Suction Valves (9)		
Diameter of Pumps (2) . .	1	1	Diameter of Discharge Valves .	0	6⅛
Length of Stroke	1	10	One set of ditto (9)		
Diameter of Pump Rod . .	0	2⅛	Diameter of Injection Pipes (2).	0	4
Diameter of Suction Valves .	0	6⅛	Diameter of Discharge Pipe .	1	3¼

INJECTION CONDENSERS FOR RETURN-ACTION ENGINES.—The type of engines, in connection with the condensers now to be noticed, interfere with the arrangement of the pumps and valves to a considerable extent. The steam piston rods have to be prolonged at the sides of the condenser, and the guides must be in close proximity. Certainly then, the authorities are to be commended for their different productions, each accomplishing the same result by dissension of opinion. As a proof of this, it must be remembered that each maker deals with the same evils common with the type of engine; therefore, no chance for escape or obviation is possible. Now with "single piston rod direct-acting" and "trunk engines," all makers of these examples can freely employ the most compact arrangement of condenser, &c., and thus the cylinders can be situated at the least possible space apart.

FIG. 35.



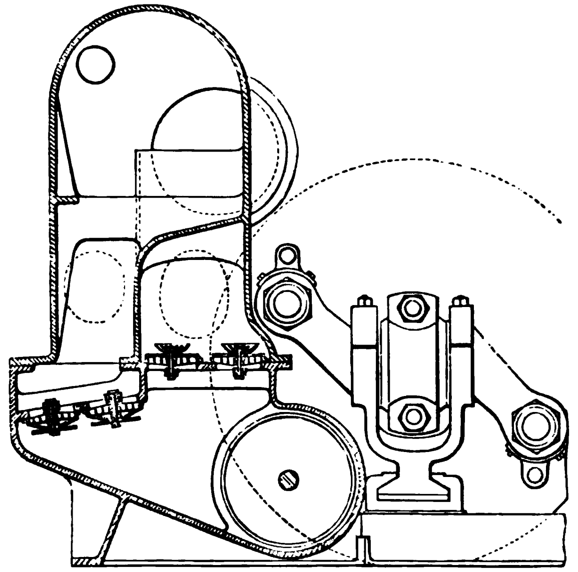
Modified Injection Condenser and Double-Acting Air-Pumps, for any class of Direct-Acting Engine, used since the year 1861.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 60			One set of Suction Valves (6)		
Diameter of Pumps (2) . . .	0	8¾	Diameter of Discharge Valves .	0	4
Length of Stroke	1	2	One set of ditto (6)		
Diameter of Pump Rod . . .	0	1	Diameter of Injection Pipe . .	0	2¾
Diameter of Suction Valves. .	0	4	Diameter of Discharge Pipe . .	0	6

It being evident also that with all engines, whether marine or not, two compartments are essential to produce condensation, such as "condensing" and "discharge" chambers, and that the former *should be above* the air-pumps, &c., the engineer has, therefore, to consider which chamber shall be centrally placed in the arrangement, or rather which shall be "fore" or "aft" of the connecting and piston rods. In conjunction with this, attention has to be given to the transverse space required for the valves, and the fact also that the "air-pumps" can be worked by the steam piston is often the cause of much trouble to obtain that connection for its motion.

This matter has resolved itself into three questions, as preliminaries: First, shall the condenser be between the *inner* piston rods of each engine, or beyond those outside the guides? —the discharge chamber being, of course, similarly effected; secondly, shall both chambers be centrally placed? and thirdly, shall the entire arrangement be outside, or fore and aft, of the rods? and thus one air-pump and condenser be away from the other.

FIG. 36.



Maudslay's Injection Condensers and Double-Acting Air-Pumps, for Double Piston Rods Return-Acting Screw Engines, used since the year 1863.

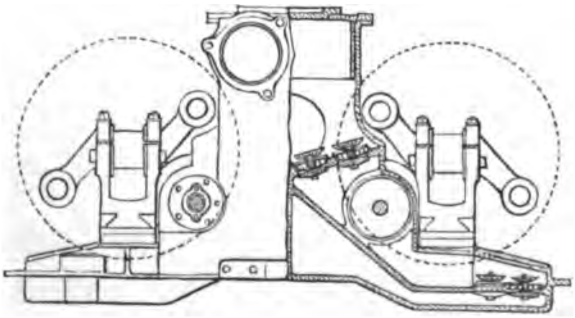
	ft.	in.		ft.	in.
Nominal H.P. of Engines, 900			One set of Suction Valves (17)		
Diameter of Pumps (2) . .	2	2½	Diameter of Discharge Valves .	0	10¾
Length of Stroke	4	0	One set of ditto (18)		
Diameter of Pump Rod . .	0	3¾	Diameter of Injection Pipes (2)	0	7
Diameter of Suction Valves .	0	10¾	Diameter of Discharge Pipes (2)	1	1¾

No firm has devised more varied examples of the type of condenser under notice than Messrs. Maudslay, Sons, and Field, and their latest and best production is illustrated by Fig. 36. The air-pump's centre is within the periphery of the cylinder, and the entire arrangement of chambers, valves, and pumps, is outside the fore and aft piston rods. The condenser is of peculiar form—common to the requirements determined—

although the discharge chamber may almost be deemed an intrusion in the former compartment. The suction valves are inverted above the pump, and those for the discharge are correctly arranged in the bottom of their respective chamber. The exhaust steam enters the condenser directly above the partition or roof of the discharge chamber, and the injection water is admitted near the roof of the condenser. Suitable doors are secured at the end of the structure to inspect or renew the valves: the discharge water, of course, passes out at the back end between the roof and base of its chamber.

This distribution of the details is as compact an arrangement as almost possible, admitting the late improvements, and that too with the evidence that practice in the hull has not belied the theory founded in the drawing office.

FIG. 37.



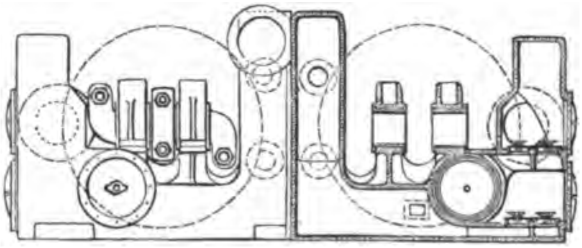
Maudslay's Injection Condenser and Double-Acting Air-Pumps, for Double Piston Rods, Return-Acting Screw Engines, used since the year 1850.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 200			One set of Suction Valves (5)		
Diameter of Pumps (2) . . .	1	1¼	Diameter of Discharge Valves .	0	7
Length of Stroke	2	0	One set of ditto (6)		
Diameter of Pump Rod . . .	0	3	Diameter of Injection Pipe . .	0	4½
Diameter of Suction Valves . .	0	7	Diameter of Discharge Pipe . .	1	2

For engines of moderate power, or about 200 horse-power nominal collectively, Messrs. Maudslay adopt the arrangement illustrated by Fig. 37. In this example the suction valves are *below* the air-pump, and those for the discharge above. The condensing compartment is at the front of the arrangement, and extends for the entire length under the air-pumps. The discharge chamber is centrally situated between and above the pumps. The exhaust steam is admitted at the front end, and the injection of water directly above. The discharge from the chamber is effected at the back end directly above the valves.

It will be noticed that due attention has been directed, by the designers, to the accessibility to the valves—the doors, for that purpose, being *above* each set rather than at the *side* of each compartment. It is also apparent that, with this and the previous example, the steam piston and air-pump rods are directly above each other, thus retaining a similar position for the pumps in relation to the cylinders, so that "arms" could be used if preferred, which is one of the important features in the subject under notice.

Fig. 38.



Ravenhill's Injection Condensers and Double-Acting Air-Pumps, for Double Piston Rods Return-Acting Screw Engines, used since the year 1857.

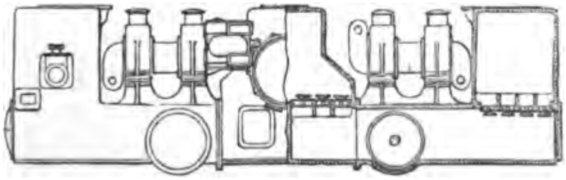
	ft.	in.		ft.	in.
Nominal H.P. of Engines, 250			One set of Suction Valves (6)		
Diameter of Pumps (2) . . .	1	3⅜	Diameter of Discharge Valves .	0	8
Length of Stroke	2	6	One set of ditto (6)		
Diameter of Pump Rod . . .	0	3	Diameter of Injection Pipes (2)	0	3
Diameter of Suction Valves . .	0	7¾	Diameter of Discharge Pipes (2)	1	1⅛

Messrs. Ravenhill and Hodgson are next to be alluded to, in connection with the present subject. This firm for some time adopted the arrangement represented by Fig. 38. In this case the condensers are separate, centrally placed, and extend under the guides for the piston rods. Almost in a vertical line below the outside piston rod, the air-pump is situated, deriving its motion from the steam piston. The suction valves are level with the bottom of the pump at the side, and those for the discharge directly above. The discharge chambers are therefore outside the piston rods, and thus both compartments form—by their positions—a channel for the main parts of each engine.

The exhaust steam enters the chamber at the front end near the roof, and the injection water is admitted directly below at the opposite end. The doors for the various purposes are at the sides of their respective chambers, and thus the entire arrangement may be termed compact and efficient.

The correct position for the condenser is—as often before stated—*above* the air-pump, and the firm in question have duly recognised this by their arrangement depicted by Fig. 39. Here it will be noticed the suction and discharge valves are *above* the pump, each set level with each other, and in reverse positions to those in the previous example. The chambers also are in contrary positions in relation to the piston rods and guides, but forming a similar channel.

FIG. 39.



Ravenhill's Injection Condensers and Double-Acting Air-Pumps, for Double Piston Rods Return-Acting Screw Engines, used since the year 1863.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 900			One set of Suction Valves (20)		
Diameter of Pumps (2) . . .	2	1¼	Diameter of Discharge Valves .	0	7½
Length of Stroke	4	0	One set of ditto (20)		
Diameter of Pump Rod . . .	0	3¾	Diameter of Injection Pipes (2) .	0	8
Diameter of Suction Valves . .	0	7	Diameter of Discharge Pipe . .	2	5½

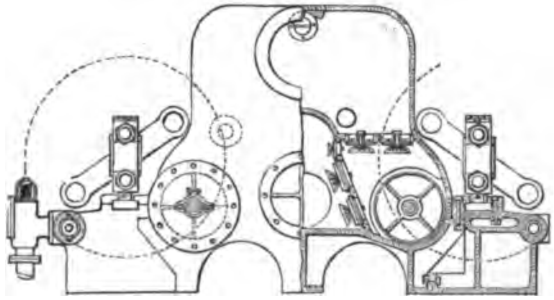
The condensers are fore and aft of the piston rods, in separate compartments common to each cylinder. The discharge chamber is centrally placed, or between the pumps over the same, and thus a single compartment is adopted in the place of duplications.

The exhaust steam enters each condenser at the roof, near the front end, and the injection water valve is at the back end. The position of each air-pump in relation to the piston rods is almost central, rather than as the prior examples, but the great distance between the valves causes a great "wash" on each side of the pump. The discharge pipe is secured at the back end directly above the valves. The means for inspection is provided for by doors, situated on the roof of the discharge chamber, and at the sides of each compartment below the condensers.

Attention is next directed to the arrangement illustrated by Fig. 40. This is originated by the author, the principal aim being to adopt the *advantages* common with the condensers for direct-acting engines, and apply them to the return-acting types in an equally simple manner.

It will be noticed that the condenser is a *single* compartment *above* the air pumps. The discharge chamber is under the condenser, between the pumps, and by this situation space is economized. The guide channels are *beyond* the structure—being a reverse position to that adopted by the Messrs. Maudslay, shown by Fig. 36, on page 40. The exhaust steam is admitted for condensation below the roof of the chamber, at the front end, opposite to which is the injection valve. The position of the suction valves are similar to that in Fig. 32, on page 35, but the discharge valves are almost vertically secured in the chamber—being unlike any of the previous examples alluded to. To ensure the air escaping on being discharged at each stroke of the piston, "air valves" are secured above the

FIG. 40.



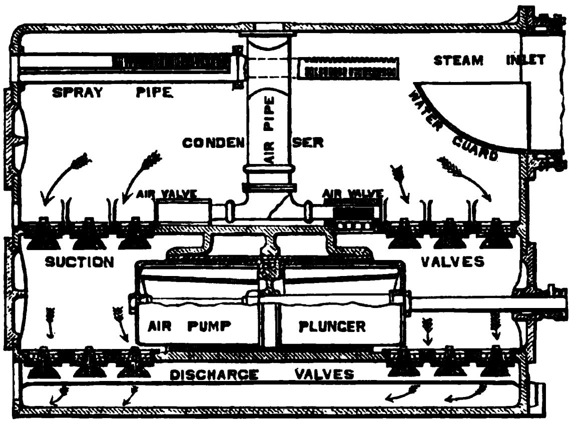
Burgh's Injection Condenser and Double-Acting Air-Pumps, for Double Piston Rods Return-Acting Screw Engines, used since the year 1863.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 200			One set of Suction Valves (8)		
Diameter of Pumps (2) . . .	1	2¾	Diameter of Discharge Valves .	0	6¾
Length of Stroke	2	0	One set of ditto (8)		
Diameter of Piston Rod . .	0	2⅜	Diameter of Injection Pipe . .	0	3¾
Diameter of Suction Valves. .	0	6½	Diameter of Discharge Pipe .	1	3½

main valves. The discharge water passes out at the back end of the chamber. The doors for access to the suction valves are those of the air-pump barrel, and those for the discharge valves are at the back and front ends of the respective chambers. In some instances the suction valves have separate doors at the sides directly above the pumps.

Relative to the discharge of the air, our attention was pertinently directed, as far back as the year 1860, to the fact that the complete discharge of the air and water from the condenser at each stroke of the pump must conduce to the better working of the latter, as well as maintaining a good vacuum in the former; and as our practice makes the acquaintance of all the best examples then and now in use, we could discern their defects and the causes, together with the advantages. This knowledge prompted the arrangement as illustrated by Figs. 41 and 42.

FIG. 41.

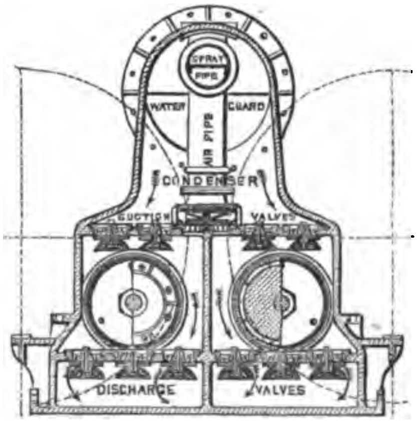


Longitudinal Sectional Elevation of Burgh's Water-falling and Air-forcing Condenser and Double-Acting Plunger Air-Pumps, for Double Piston Rods Return-Acting Screw Engines, applied in the year 1862.

The valves are *all* inverted over and under the pumps, so as to allow the water to *fall* from the condenser, and thence through the lower valves, and is next by the plungers forced from the lower chamber through the discharge pipe into the sea or river. Thus the water was discharged, but we had the air remaining, because it always rises to the surface of fluids when a disturbance occurs; and to force out the air in the pump we put two valves, working upwards in casings, which are connected by a pipe that extends to the roof of the condenser; from there a pipe led to the main water discharge opening in the ship's side: thus the water passed away from the base of the arrangement and the air from the roof.

Besides the advantage of causing almost a perfect vacuum, this arrangement admitted that the steam cylinders could be brought as close together as their diameters allowed, as shown in dotted lines in Fig. 42; while also the condenser and pump casings were within the vertical centre line of each cylinder, a fact not obtainable by any other arrangement.

FIG. 42.

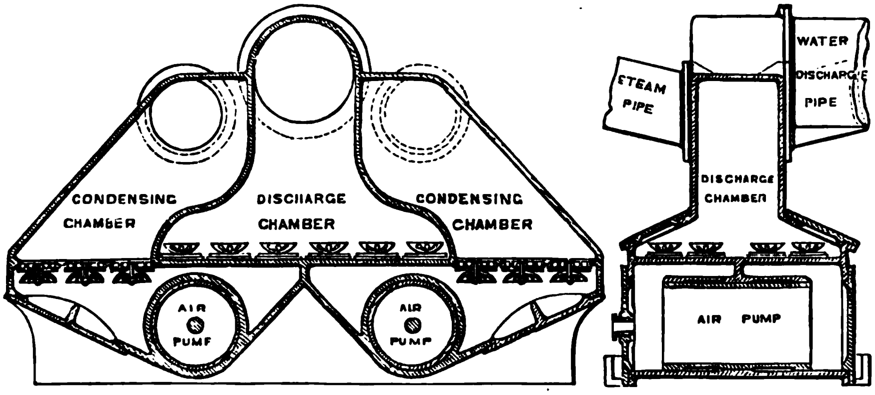


Transverse Sectional Elevation of Burgh's Water-falling and Air-forcing Condenser and Double-Acting Plunger Air-Pumps, for Double Piston Rods Return-Acting Screw Engines, applied in the year 1862.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 400			Diameter of Discharge Valves .	0	7½
Diameter of Pumps (2) . . .	1	6	One set of ditto (9)		
Length of Stroke	3	0	Diameter of Injection Pipe . .	0	5½
Diameter of Piston Rod . . .	0	2½	Diameter of Water Discharge Pipe	1	11½
Diameter of Suction Valves . .	0	7½	Diameter of Air Pipe . . .	0	7
One set of ditto (6)					

In the year 1865 considerable agitation was in force amongst the Admiralty officials—and of course the marine engineering contractors felt the shock—as to the best means of adopting twin screw propellers. There was no doubt about their efficiency, but there was about the engines being put into a small space; in fact, to occupy more room than those for the single adaption would have been considered a barrier to the success of the other. It happened therefore that designs were sent in from all quarters, some with the condensers across midships, and others at the sides, the cylinders being reversely situated.

Fig. 43.

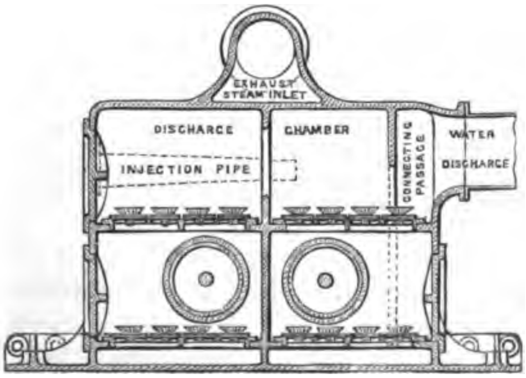


Burgh's Injection Condenser and Double-Acting Air-Pumps—one for a pair of cylinders—for Twin Screw Engines, invented in the year 1865.

	ft.	in.
Nominal H.P. of Engines, 100		
Diameter of Air-Pump . .	0	11½
Depth of Piston	0	3½
Diameter of Piston Rod . .	0	1¾
Stroke	1	6

Area of one set of Suction Valves	80	sq. in.
Area of one set of Discharge Valves	90	„
Number of each kind (6)	ft.	in.
Diameter of Discharge Pipe .	1	1
Diameter of Injection Pipes (2) .	0	2

Fig. 44.

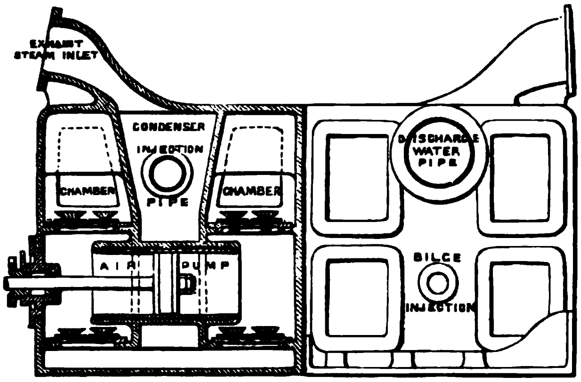


Watt's Injection Condenser and Air-Pumps for Horizontal Direct-Acting Screw Engines, constructed in the year 1866.

We amongst the rest did our best; and thus the arrangement illustrated by Fig. 43, on the preceding page, was originated, being based on the fact that the greatest weight in a ship should be on the keel, or "thereabouts." Consequently we put the condensers and pumps in the centre of the "ship" transversely, and the cylinders as near that as practicable, with the piston rods' guides beyond, and also the supplementary pumps.

A very good arrangement of duplicate condenser and pumps was designed and constructed by Messrs. James Watt and Co., for twin screw engines, in the year 1866, as illustrated by Fig. 44 in transverse, and by Fig. 45 in longitudinal, sectional, and complete elevations.

FIG. 45.



Watt's Injection Condenser and Air-Pumps for Horizontal Direct-Acting Screw Engines, constructed in the year 1866.

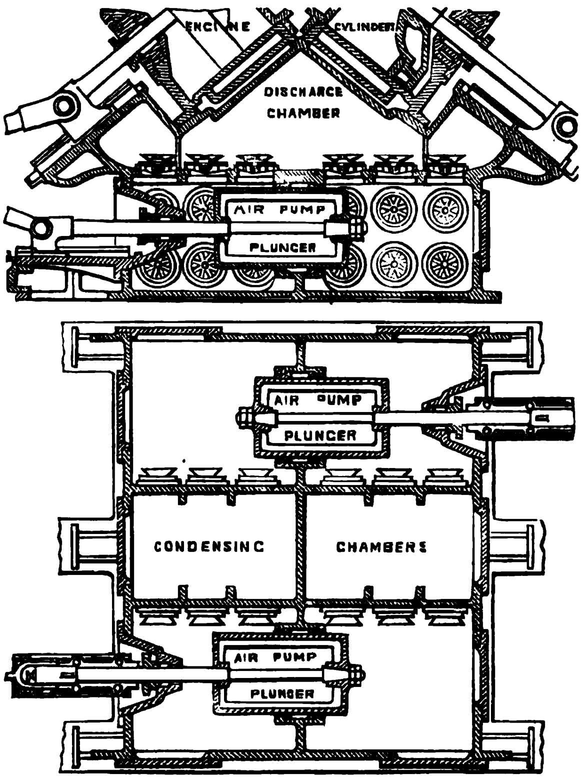
Nominal H.P. of Engines (2), 100

	ft.	in.		
Diameter of Air-Pump . .	0	10	Diameter of Water Discharge Pipe	11 in.
Length of Stroke	1	8	Area of one set of Suction Valves	70 sq. in.
Depth of Piston	0	4	Area of one set of Discharge Valves	72 „
Diameter of Injection Pipe . .	0	3		

The condenser is in the centre of the structure in the above view, but in that preceding it is shown to extend to about seven inches from the discharge side, the remaining space forming the connecting passage of the two discharge chambers that are at the ends of the pump barrels, as seen in the longitudinal view. The sea injection pipe is shown in both the sectional views, and the bilge injection inlet in the complete elevation, where are also the valve-doors and discharge water-pipe shown.

The arrangement of pumps and condenser shown below is for twin-screw engines also, by Messrs. Dudgeon. Each plunger is worked by a connecting rod on the main crank pin, on each side: the condenser is between the pumps, and the discharge chambers directly over them: the suction valves are vertically situated, and those for the discharge horizontally.

FIG. 45a.



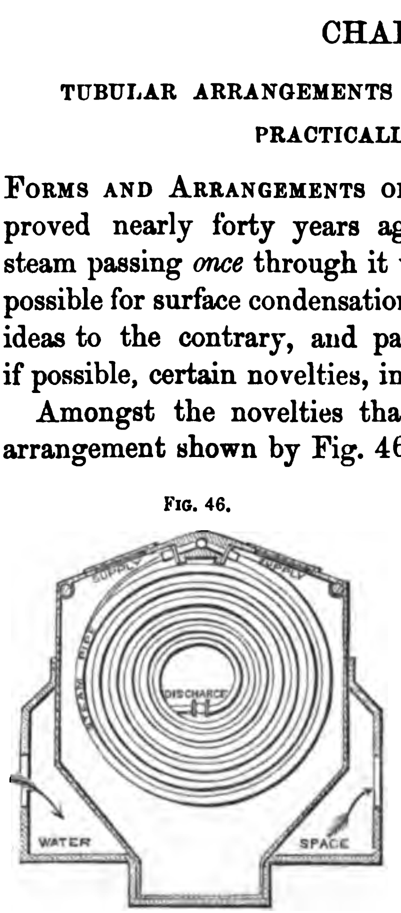
Dudgeon's Plunger-Pumps and Condenser for Inverted Angular Twin-Screw Direct-Acting Engines, constructed in the year 1869.

CHAPTER V.

TUBULAR ARRANGEMENTS FOR SURFACE CONDENSATION PRACTICALLY CONSIDERED.

Forms and Arrangements of Tubes.—Although it had been proved nearly forty years ago that a straight tube and the steam passing *once* through it was the simplest and best method possible for surface condensation, yet inventors raised new-fangled ideas to the contrary, and patented them too, to substantiate, if possible, certain novelties, in spite of their uselessness.

Fig. 46.



Elder's Spiral Tubes for Surface Condensers, patented in the year 1859.

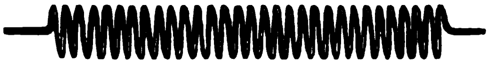
Amongst the novelties that were thrust into notice was the arrangement shown by Fig. 46, being an end sectional elevation of two sets of spiral tubes, through which steam or water is drawn by pumps, according whether inside or outside condensation was used: this had the very practical error of not being available to be cleansed inside without entire disconnection, and consequently soon became a paper scheme only.

But that did not hinder a Mr. Selby from patenting the corkscrew tube, as shown by Fig. 47, which is more difficult to "clean out" than the former: in fact, if it became nearly choked it became worthless.

Of course it is admitted and understood that an excess of surface was the main consideration in those cases, but when that was at the sacrifice of cleansing and repair, the idea became useless in practice.

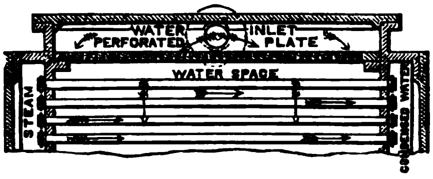
Two years before the last date, no less a person than Mr. James Jack, of Liverpool, came before the public with his two notions of surface condensation. His first, as shown by Fig. 48, was to use Hall's old perforated plate, which we have shown by Fig. 5, on page 9, and to patent it also, terming it "his improved perforated attachment, through which the water is allowed to fall on horizontal tubes." His second claim was as illustrated by Fig. 49, in which the tubes are syphons, and

Fig. 47.



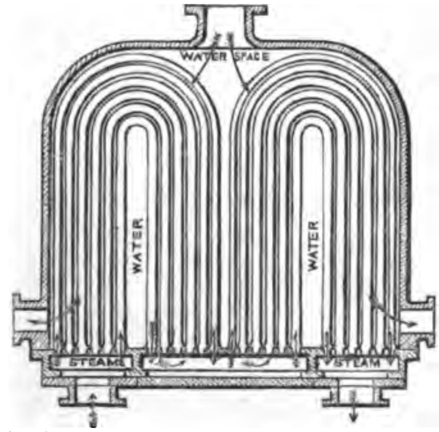
Selby's Corkscrew Tube for Surface Condensation, patented in the year 1862.

Fig. 48.



Jack's Perforated Plate for the Water to fall in a Shower on the Tubes, patented in the year 1860, but used by Hall in the year 1833.

Fig. 49.

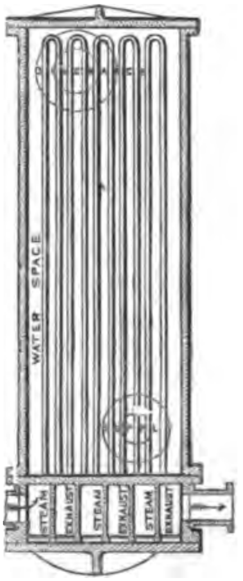


Jack's Syphon Tubes for Surface Condensation, patented in the year 1862.

therefore require only one plate to secure them to: there was some novelty in this, but it had the objection of difficult cleansing inside, particularly the narrowest syhpon tube.

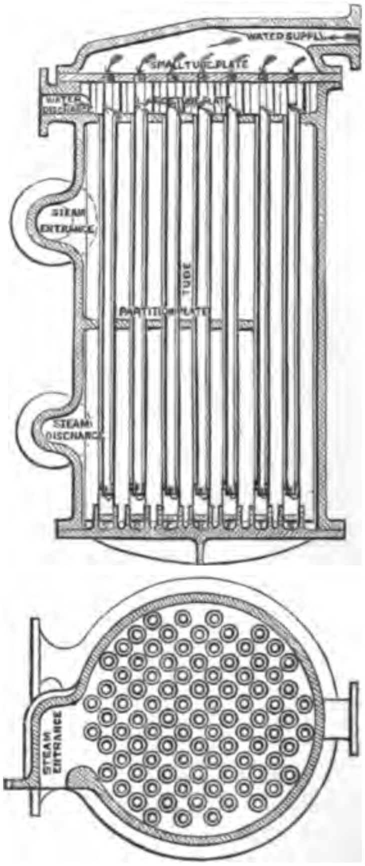
Directly after, in the same year, 1862, Mr. Allibon and his friend, Mr. Snell, conceived the arrangement as shown by Fig. 50. In this case Mr. Jack's syphon tubes were copied and applied to convey the steam from one chamber into another, until the process of condensation was sufficiently accomplished.

Fig. 50.



Allibon's Arrangement of Syphon Tubes and Chambers for Surface Condensation, patented in the year 1862.

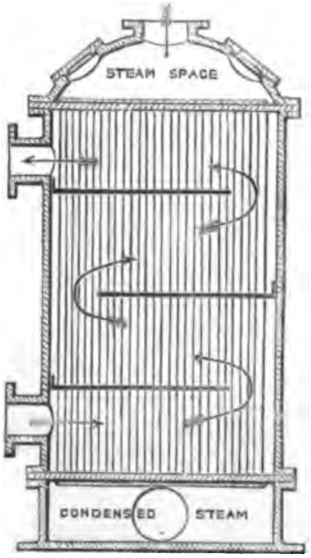
Fig. 51.



Miller's Circulating Water-Tubes for Surface Condensation, patented in the year 1869.

The next example of complications we refer to is by an American inventor, a Mr. Miller. This surface condenser is illustrated by Fig. 51. The outer tubes are secured at one end only, which end is inserted into the plate, the other end of the said tubes being closed in sockets, as shown; those closed ends are free to move endwise in the sockets, so that the tubes may expand and contract under variations of temperature, while the free circulation of the water within the tubes is ensured by the arrangement therein of the inner tubes. These small tubes are placed inside the large tubes, and have their ends secured in the top plate; and it will be seen that these inner tubes extend nearly to the free end of the outer tubes, where they are supported by pins, which do not impede the circulation of the water through the tubes. The water enters the condenser at the top, and flows through the inner tubes, and returns through the outer tubes, and after absorbing the heat from the steam is discharged from the condenser by the discharge pipe, situated on one side under the small-tube plate. The steam on entering, passes up between the outer tubes over the top of the partition plate, and then passes down among the tubes to the discharge opening, through which the products of condensation leave the condenser. As only one end of the tubes is fixed and the other end free, no packing is required, and there will be no leaking of the joints or other injury to the condenser by the expansion or contraction of the tubes.

FIG. 52.

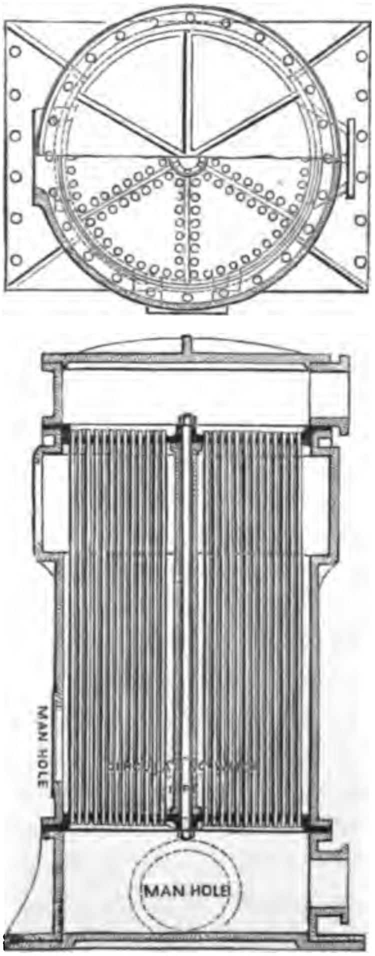


Rowan's Circular Surface Condenser, the Steam passing direct through the Tubes, and the Water mechanically circulating around them, patented in the year 1869.

In the same year Mr. Rowan came forward with an excellent arrangement for a vertical circular surface condenser, as illustrated by Fig. 52. He employed Hall's "inside" traverse for the steam, but by plates—through which the tubes passed, between the tube plates—mechanically circulated the water around the tubes.

Retracing our steps a little, we direct attention to the now universal English arrangement, which was introduced about the year 1865, and has since become a special favourite by all the leading marine engineers of Great Britain. This is illustrated in sectional elevation by Fig. 53, and is arranged for either inside or outside condensation. The connection, or jointing, of the separate portions are much to be commended, it being a really "good job," taking into consideration access for inspection, cleaning, repair, and economical construction.

FIG. 53.



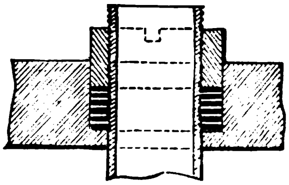
Universal English Arrangement for the Tubes of a Vertical Circular Surface Condenser, used since the year 1865.

CHAPTER VI.

TUBE PACKINGS FOR SURFACE CONDENSATION PRACTICALLY CONSIDERED.

Screwed Tubes and Gland Packings.—When Hall began to introduce his system of surface condensation, no little trouble was found in packing the tubes. His first attempt is shown by Fig. 4, on page 8: in that case he used nuts on the tube inside and outside the plate, and conically recessed the latter in the hole to receive the packing; that was, however, double duty to accomplish a single purpose, the contrast being illustrated by Fig. 54, to prove our remark. Here the tube is screwed with the gland on it, as a nut, and a parallel recess formed in the plate to receive the packing, so that the "under" nut, as Hall used, is not required.

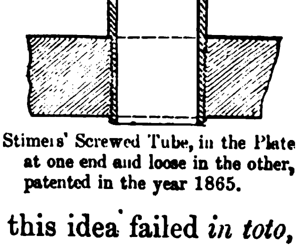
Fig. 54.



Screwed Tube and Gland Packing, adapted generally since the year 1840.

Fifteen years after this an American, named Stimers, introduced his idea for screwed tubes, as illustrated by Fig. 55: this was very simple indeed, being but a screwed connection with one plate and none with the other, and the top of the tube was slotted to use that end as a screw. We need scarcely remark that this idea failed *in toto*, and serves but as warning to young engineers.

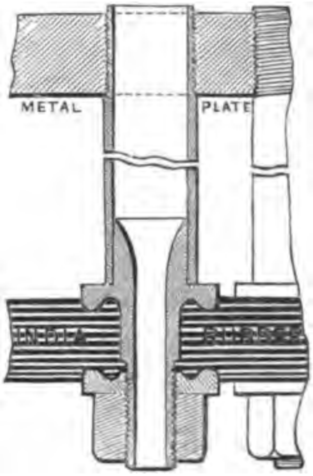
Fig. 55.



Stimers' Screwed Tube, in the Plate at one end and loose in the other, patented in the year 1865.

No later than the year 1869, a Mr. Bennett patented the arrangement of a screwed nozzle packing, as shown by Fig. 56, in combination with an *indiarubber tube plate* in the place of an ordinary brass one. This was reversing the application of the materials, and Mr. Bennett claimed that there would be an advantage in doing so, for he stated "that the elasticity of the tube plate would permit the expansion and contraction of the tube without affecting the joint," the other end of which he screwed into the metal plate as Stimers had done previously.

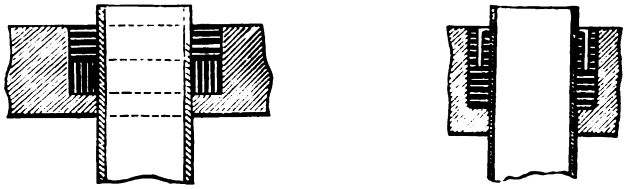
FIG. 56.



Bennett's Screwed Nozzle Packing, with Washer and Nut to fix in an Indiarubber Plate, patented in the year 1869.

PLAIN TUBES AND SELF-ACTING PACKING.—When Hall introduced his gland packing, as illustrated by Fig. 7, on page 10, he did a "good thing" for the promotion of surface condensation; and about thirteen years ago, Mr. Spencer, the well-known advocate for the system, tried to improve on it by an arrangement of self-acting packing, as illustrated by Fig. 57, on the left hand, which was the most economical means known,

FIG. 57.



Spencer's Self-Acting Tube Packing, used since the year 1858.

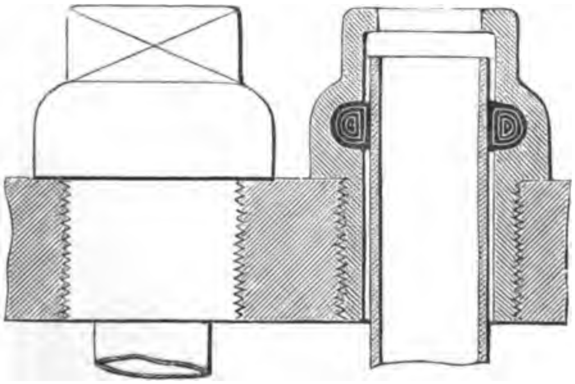
Marshall's Self-Acting Tube Packing, patented in the year 1869.

it being simply two square section rings of indiarubber forced into the recess in the plate around the tube, and as the circulating water passed through the tubes it pressed on the packing also, and caused the joint to be tight. Very lately a Mr. Marshall patented the packing shown on the right hand, which is a split ring of indiarubber, instead of two solid rings as Spencer uses. We may add those methods were all "very well" while the packings were elastic; but directly they became dry and hard a leakage occurred, which was as provoking as disastrous.

Another self-acting ring-packing is shown by Fig. 58, which consists of a nozzle screwed into the plate for each tube, and the ring contained in a recess in the nozzle.

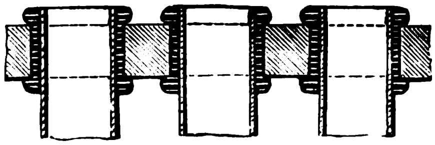
To "pack the tube" the ring is first put in the recess, the nozzle is then screwed "up;" next the tube has a metal cone-piece put in its end, which enables the tube to pass through the ring readily, and by taking the cone away the joint is made. This is the simplest method for "ring-packing," as far as labour of packing is concerned, we know of; but the manufacture to arrive at that stage is very expensive; indeed, sufficient to nearly condemn the application.

FIG. 58.



Winton's Self-Acting Tube Packing, proposed in the year 1863.

FIG. 59.



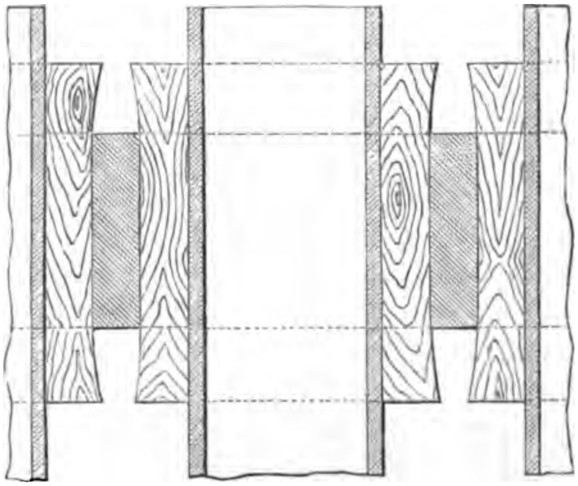
Furlonge's Self-Acting Tube Packing, patented in the year 1861.

Now if reliance can be put in the continuance of the elasticity of indiarubber, or its equivalent compound, the illustration, Fig. 59, is the simplest self-acting packing arrangement before us, because the hole in the plate is a plain one—"right through alike"—without recessing or screwing, and therefore labour is reduced to the smallest limit. This was patented by a Mr. Furlonge in the year 1851, but has not yet received much favour by the makers and workers of surface condensers.

At the end of the year 1866 a Mr. Horn introduced a novel kind of tube packing, as shown by Fig. 60, which was originated by a Mr. Allen, in America, about one year before.

Here wood was used, in the place of metal, indiarubber, or cotton, by simply making it in short tubes, or long rings, and forcing them into smaller holes than their original diameters, the proportion being about $\frac{1}{16}$ inch less for each $\frac{1}{4}$ inch of the tube's diameter. As for example, for a $\frac{3}{4}$ inch tube outside, the hole in the plate would be $\frac{15}{16}$ inch diameter, but the wood packing normally is $1\frac{1}{8}$ inch in diameter, and when fitted in, swells at the extremities as represented, and tightens inside and outside at the same time.

FIG. 60.

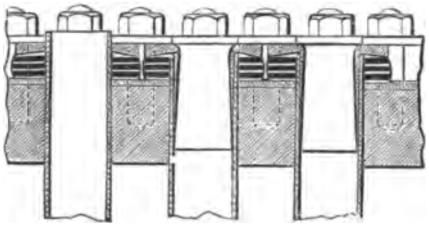


Horn's Wood Self-Acting Tube Packing, introduced in the year 1866.

PLAIN TUBES AND PLATE PACKING.—This class of packing consists chiefly in the economy of labour in "screwing-up" the glands, or compressing the packing of any number of tubes, at once rather than each separately.

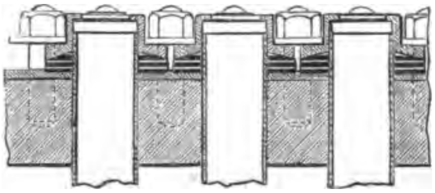
Mr. Macnab, in the year 1860, patented his ideas on this subject, as shown by Fig. 61. On the left hand a single tube is shown as packed by an indiarubber and metal washers, and on the right hand two tubes packed with ferrules, as an addition to the other, are illustrated.

FIG. 61.



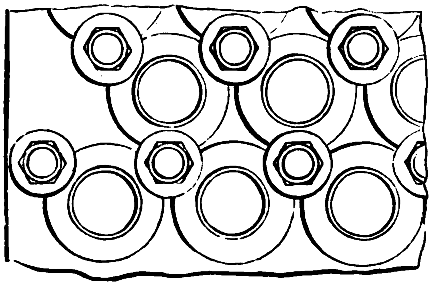
Macnab's Washer and Ferrule Tube Packing, patented in the year 1860.

FIG. 62.



Macnab's Flanged-ring Tube Packing, patented in the year 1860.

FIG. 63.



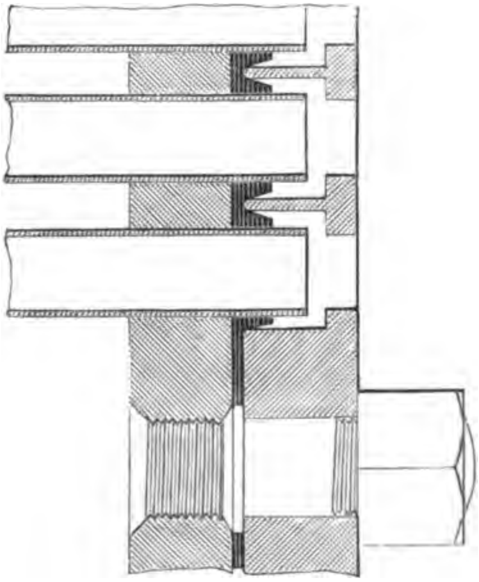
Macnab's Washer Tube Packing, as seen in plan, patented in the year 1860.

Another method is shown by Fig. 62. In this case flanged-ring washers were used, which covered the ends of the tubes as well as surrounded them, but what is accomplished by such an arrangement is not yet known.

As to the worst position of the tubes relatively with the packings proposed, Mr. Macnab seemed to have been in a state of happy ignorance, which fact is illustrated by Fig. 63, where it can be seen that in the aggregate there are required a stud, nut, and washer, with each tube-packing, and those details keep the tubes farther apart than would otherwise occur.

About this time a Mr. Sewell patented a plate packing, as shown by Fig. 64. This arrangement required a separate metal plate, formed with holes and recesses of the same "pitch" as the tubes, and also a sheet of indiarubber similarly perforated.

FIG. 64.



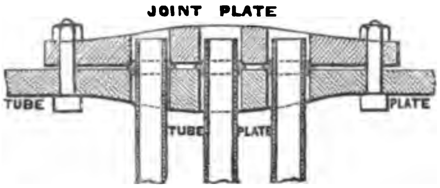
Sewell's Plate Tube Packing, patented in the year 1860.

The method of applying those details is this: the indiarubber plate is put on the tubes and pressed around them, until they protrude; the metal plate is put in position, and the nuts on the set studs "screw up" the plate, and thus compress the indiarubber sufficiently to make *all* the tube joints perfect at the same moment. The advantage with this is merely in the latter attainment, because in the case of repair or renewal the outer plate must be removed, even for a single tube. This arrangement has gained much favour in England and America, on account of the facility for packing all the tubes at once, and thus economising the time and labour of the contractors.

In our memorable Exhibition year, 1862, a French gentleman, named M. de Normandy, patented the method of plate packing as illustrated by Fig. 65. This was the application of a plate as Sewell's, but instead of a single plate of indiarubber, separate rings of that material were used on the ends of the tubes, and they were compressed as shown to make the joints perfect by the bolts and nuts.

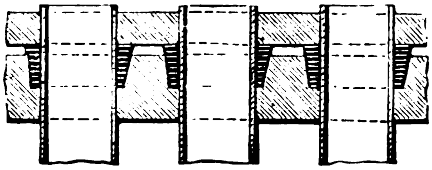
The American engineers about this period tried various methods of tube packing, which were nearly all on the "Sewell" plan, *i.e.*, a set plate, termed a "follower," and in the place of the single plate of indiarubber, rings were used, and plain glands, or the follower was in portions rather than a single plate. After various contrivances the arrangement shown by Fig. 66 was introduced, which is the simplest, and equally effective. Here the tube plate was drilled for the tubes and recessed for the packing, that being merely rings of indiarubber, on which the set plate acted: this was used with success, and soon became popular.

FIG. 65.



M. de Normandy's Plate and Rings Tube Packing, patented in the year 1862.

FIG. 66.



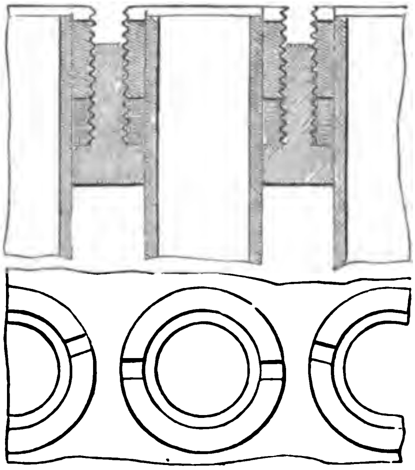
American Plate and Rings Tube Packing, introduced in the year 1862.

Screwed Gland Tube Packing.—Although this has been referred to on page 10, we have thought it worthy of an extended notice, as it is the most practically safe packing yet known, and is now universally used in our royal and mercantile navies as the most endurable and the best.

The late Edward Humphrys used this packing extensively, and in the year 1862 he stated his experience. The proportions he used are illustrated by Fig. 67. Speaking of a marine condenser he had tried for some time successfully, he said :—

"Each condenser contains 1178 seamless drawn pure copper tubes, $\frac{5}{8}$ inch outside diameter and No. 18 wire-guage or ·05 inch thick, 5 feet 10 inches long, weighing 28 ozs. each tube, and fixed at 1 inch pitch from centre to centre. The tube plates are of cast gun-metal $\frac{3}{4}$ inch thick. These are first set as flat as possible, and the tube holes marked out upon them. The holes are then drilled under a common drilling machine with a drill of two diameters, having a guard upon it to fix the depth to which the larger diameter shall penetrate the plate. One machine worked by an ordinary driller drilled the 1178 holes in the tube plate in 70 hours. The tapping of the holes is then

Fig. 67.



Humphry's Proportions for Hall's Screwed Gland Tube Packing, as used in the year 1862.

proceeded with, and is effected with a tap, having a parallel end to guide it, which fits the smaller diameter of the tube holes. One man of ordinary skill tapped the 1178 holes in the plate in 70 hours. After having been drilled and tapped, the tube plate is again set perfectly flat on a surface plate, and then both sides are faced off in a lathe or planing machine."

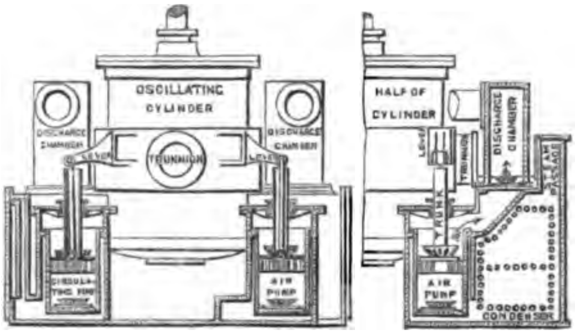
The screwed glands, for securing the packing at the ends of the tubes, are made from Muntz metal solid-rolled tubes, which are obtained in lengths of about five feet, rolled to gauge both inside and outside; the inside diameter is exactly that of the outside of the copper tubes, namely $\frac{5}{8}$ inch, and the outside diameter is such that when screwed it will exactly fit the tapped holes in the tube plates. It is screwed on the outside as it comes from the maker in a common screwing machine, and is then cut by a circular saw into half-inch lengths to form the glands. The saw marks are taken off the ends by a facing cutter revolving on a lathe, and the same operation clears out the inside of the hole. The notch for the screwdriver is cut by passing a number of the glands, when screwed into a plate, under a revolving circular saw of the required thickness. The packing is composed of linen tape; a piece of this tape 12 inches long, $\frac{7}{16}$ inch wide, is wound round a mandril, the ends and edges being slightly stitched, in which state it is readily put into the tapped holes of the tube plate, and when screwed down by the gland forms a very perfect and lasting joint. The thickness of the tape is such that 1300 of these packings weigh about 2 lbs.

CHAPTER VII

SURFACE CONDENSERS FOR PADDLE-WHEEL ENGINES PRACTICALLY CONSIDERED.

WE commence this chapter with the notice of an arrangement that was copied from the old method of working the feed and bilge pumps by levers or projections from the cylinder, the copier being a Mr. Davison, and his modification is illustrated by Fig. 68, which consists of the pumps being worked as described, with a condenser for each cylinder, situated in the "wing" of the engine-room. We may add that the piston rods of the engine cylinders were *guided* over the covers to resist the strain incurred by the pump's actions.

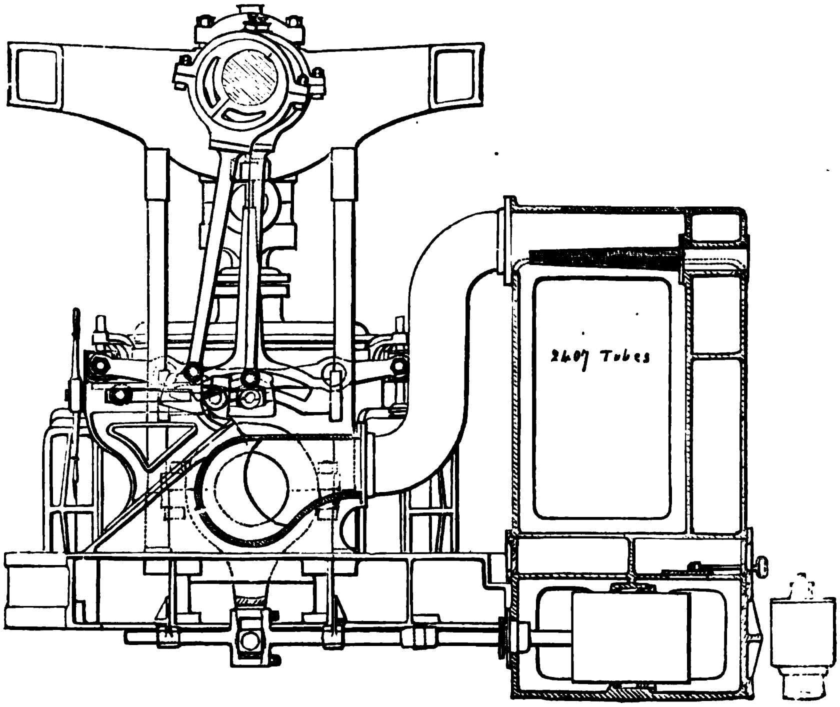
FIG. 68.



Davison's Arrangement of Surface Condensers and Pumps for Oscillating Paddle-Wheel Engines, patented in the year 1861.

Very soon after this Messrs. James Watt constructed engines and condensers, as shown in sectional elevation and complete plan by Figs. 69 and 70. The motions for the pumps were taken from the trunnions, by levers which connect to the block pins in the loops of the rods. As this is a very novel arrangement and has succeeded well, we add the following particulars of the complete arrangement. The condenser is fitted with 2,407 tubes, each 6 feet long and ½ inch inside diameter. The circulating and air pumps are each 18 inches in diameter, and the stroke the same in length. The arm secured on the cylinder gudgeon imparts motion to the rod connected to each pump, and the slot added to the rod prevents the vibration curve, or versed sine, affecting the motion. The rods are guided fore and aft of the centre of motion by brackets each 4 inches long, secured to the lower frames. The arm clasps the rod by a double eye, the brasses being sustained in the slot, and the

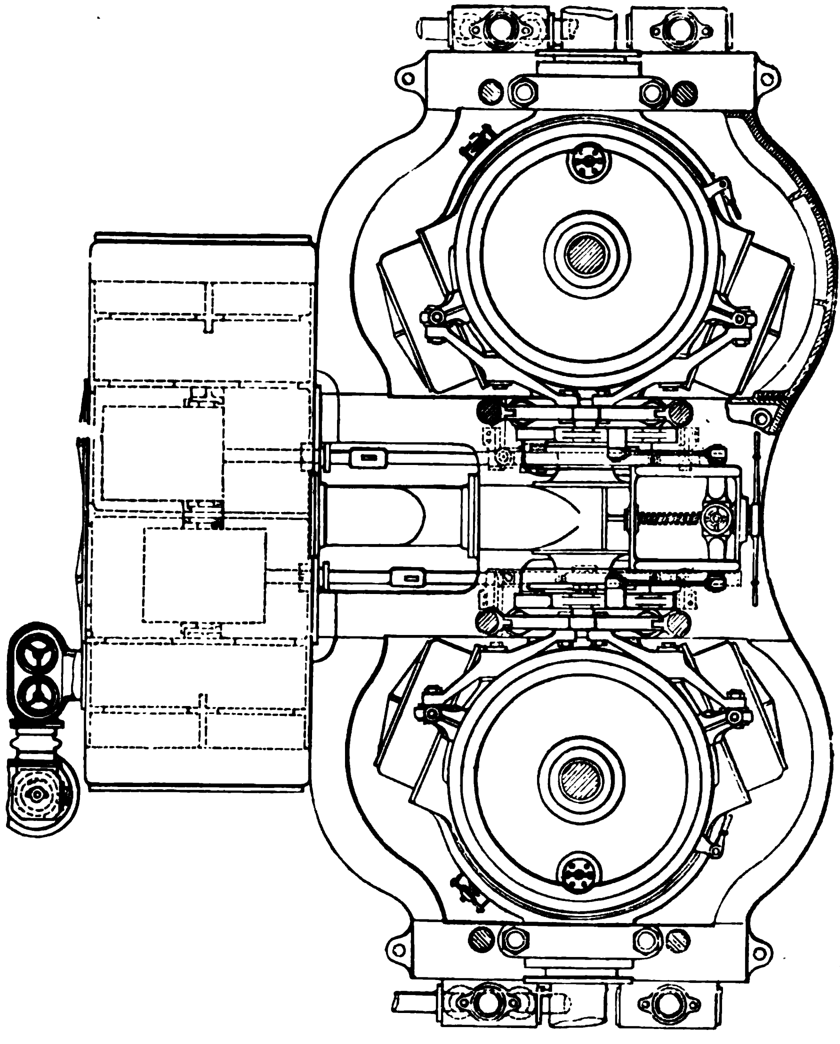
FIG. 69.



Watt's Arrangement of Surface Condensers and Pumps for Oscillating Paddle-Wheel Engines, constructed in the year 1866.

connecting pin 3 inches in diameter is of the usual kind. Each rod is $2\frac{1}{2}$ inches in diameter, and 4 feet $5\frac{1}{2}$ inches long, from the connecting socket, the length of which is $6\frac{1}{2}$ inches, and its diameter 4 inches. The length of the arm, between centres, is 2 feet $5\frac{1}{8}$ inches, therefore the versed sine of the arc of motion $= 1{\cdot}4$ inches. The length of the working barrel or plunger of the pump is 1 foot 11 inches, and the depth of the packing

FIG. 70.



Watt's Arrangement of Surface Condensers and Pumps for Oscillating Paddle-Wheel Engines, constructed in the year 1866.

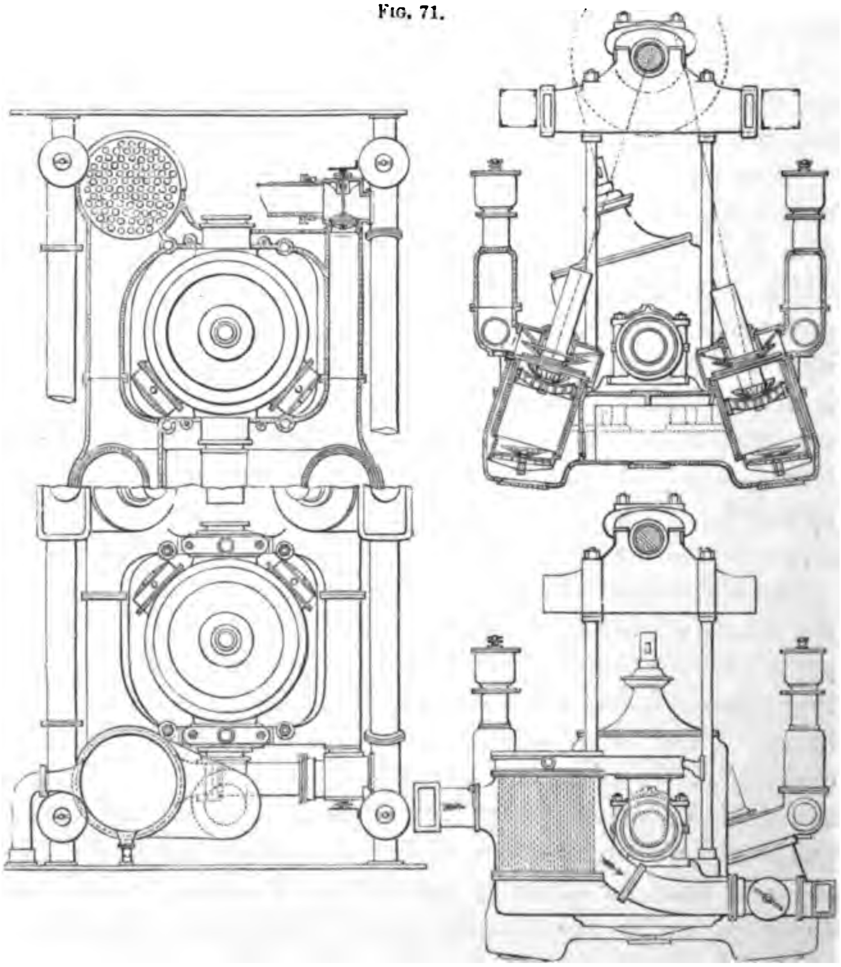
groove 4 inches. The exhaust steam pipe, 11 inches internal diameter, is connected to the top of the condenser. Opposite to which connection an injection pipe is secured, perforated all round; the diameter of the pipe at the flange is 4 inches and at the extremity 2½ inches, the length being 2 feet 6 inches. This pipe is of course only used when the tubes are out of order or the injection system of condensation preferred. The length of the condenser in the present view is 3 feet 9 inches, and the height 7 feet 9½ inches.

Thus far the elevation is understood, and the plan must next engage attention. This view is represented by Fig. 70. The link motion and starting gear is the peculiar kind which Messrs. Watt introduced about fifteen years ago. The gear consists of a sliding crosshead, guided at each end, and connected beyond the guides by rods to the links: the crosshead is worked forth and back by a screw passing through it, that is supported at each end between the guides. The securing of the links in any position is attained by the screw being surrounded by two set blocks, in the crosshead, that are set or released by a set-screw and wheel-handle.

The diameter of each of the cylinders is 3 feet 7½ inches, and the length of the stroke of piston 4 feet, equal to 120 horse-power nominal collectively. The distance between the centres of the cylinders is 8 feet 4 inches, and that for the pumps 1 foot 10 inches. It will thus be understood that the pumps are situated centrally of the width of the condenser: it is almost needless to add that, only two pumps are adopted—one exhaust steam gudgeon imparting motion to the circulating pump and the other to that for draining the condenser. The suction and discharge valves are suitably placed, and doors respectively secured, for access, inspection, and repair. The extreme width of the condenser, transversely of the hull, is 8 feet 10½ inches.

In the year 1863, the firm of Messrs. Day and Co. patented the arrangement as shown by Fig. 71, on the next page. This illustration shows the plan half in section half complete. The elevations are shown also complete and in section: the internal portion relating to the pumps only. The plan represents the condensers beyond each steam cylinder, near the sides of the hull, the pumps being centrally situated as for the injection system. The steam, it will be seen, enters the cylinders through the inner trunnions, and discharges through those on the extreme sides of the arrangement, and thence to the condensers. The pipes and stop valves are suitably arranged in connection with the pumps, condenser, and the sides of the hull. The

FIG. 71.



Day's Arrangement of Surface Condenser and Pumps for Oscillating Paddle-Wheel Engines, constructed in the year 1865.

complete elevation shows one condenser,—the tubes being dotted—the discharge and supply pipes, air vessels, and pumps, also the entablature and steam cylinder. The sectional elevation represents each pump in section, also the discharge chambers, and the vertical stop valve boxes complete.

The motion for the pumps is derived from the intermediate cranked shaft, or eccentrics can be adopted if preferred. The action of the pumps is as follows: the air pump is on the same side of the centre line as the condensers, or between the same. The steam enters the condenser at the top of the tube compartment—the connection is seen in the elevation—after passing through the tubes the condensed steam passes through the passage—seen in section in plan—to the air pump: the arrangement of the valves being shown in the sectional elevation. The discharge is effected into the chamber over the pump, and thence into the sea, if requisite, by the pipes connected to the ship's side: but generally into the boilers. If separate or feed pumps are adopted, they are connected to the opening shown in the bottom of the discharge chamber. The circulating pump is situated opposite to that last alluded to, the connection with the discharge chambers and arrangement of the valves being also similar. The sea water flows into the *upper* portion of the condenser; through the pipe shown in the plan and elevation; the drainage being through the pipes, also seen in the plan and elevation. The arrows shown in the elevation, indicate the line of the water's circuit through the condenser. The final discharge is effected through the discharge pipes, over the pump, connected to the ship's side.

In the event of fracture or leakage of the condensing tubes, or the conversion of the surface into an injection condenser, it is thus occasioned. The stop valves for regulating the circulating water connected to the pipes leading from the condenser are closed—as shown in section in plan. Injection water is admitted through the cock or valve—shown in plan and elevation—connected to the condenser above the tubes. This water meeting the steam from the trunnions, condensation occurs, and the air pump drains and discharges as before. A communication with the circulating pump is effected by the removal of the internal door—shown in the sectional elevation—at the side of the air pump near the foot valve. By this reverse adoption of the several passages, both pumps perform the same duty, and the system of condensation altered accordingly. The utility of the remaining stop valves is so obvious that a notice of them is unnecessary.

This arrangement is novel and efficacious, but at the same time wanting perfection of situation for the pumps, in relation to the condenser. It will be remembered that the former are at the centre of the hull, but the latter at the sides of the same. Now with engines of moderate power this arrangement may not be deemed objectionable, but in large engines the distance between the suction valves and the condenser will always lower their action, to say nothing of the "back-wash" always under the condensing tubes. A partial remedy for this can be caused by putting a second set of valves vertically, secured near the condensers in the passages leading from the same to the pumps.

The firm in question have fitted the mail steamer "Syria," belonging to the P. & O. Company, with engines and condensers as those illustrated in the year 1866.

The collective nominal horse power is 450, and the diameter of each cylinder 76 inches, with a length of stroke of 7 feet. The surface condensers have been very successful, producing a vacuum of 27·5 inches, with a temperature of 130° Fahr. for the feed water, which is a good attainment.

Messrs. J. and G. Rennie about the same time fitted the "Nyanza," a sister mail steamer to the "Syria," belonging to the same Company, with surface condensers and oscillating paddle engines. The condensers are arranged in the side wings of the engine room, and the air pumps centrally of the engines, as for the ordinary injection condensers—which latter are fitted also in the case of requirement. In the place of a crank on the intermediate shaft, the firm in question preferred eccentrics of a throw of 1 foot 4½ inches to impart motion to the air pumps, each pump being 3 feet 10½ inches in diameter. To accomplish this, the eccentrics are each 5 feet 2 inches diameter, the intermediate shaft being at that part 22 inches diameter. The eccentrics are doubtless the largest yet constructed. The surface condensers are tubular, both containing 8,700 tubes; each tube is $\frac{9}{16}$ of an inch in diameter; the total lineal length being 43,000 feet. The engines are 450 horse power nominal collectively, the cooling surface of the condensers are therefore 14·06 square feet per nominal horse power. The diameter of each steam cylinder is 6 feet 6 $\frac{7}{16}$ inches, and the length of stroke for the piston 7 feet. The diameter of the steel piston rods are 9¾ inches, and the crank shaft at bearings 18 inches. The paddle wheels are 27 feet diameter, with feathering floats each 10 feet long and 4 feet 6 inches wide.

With a mean pressure of steam at 25·625 lbs. on the square inch, vacuum 26·125 lbs., the engines attained 24·875 revolutions per minute, producing 2,600 horse power collectively, and propelled the vessel 13·5 knots per hour.

The circulating water is forced through the condenser, by centrifugal pumps and separate high-speed engines.

CHAPTER VIII.

SURFACE CONDENSERS FOR INVERTED VERTICAL DIRECT-ACTING SCREW ENGINES, PRACTICALLY CONSIDERED.

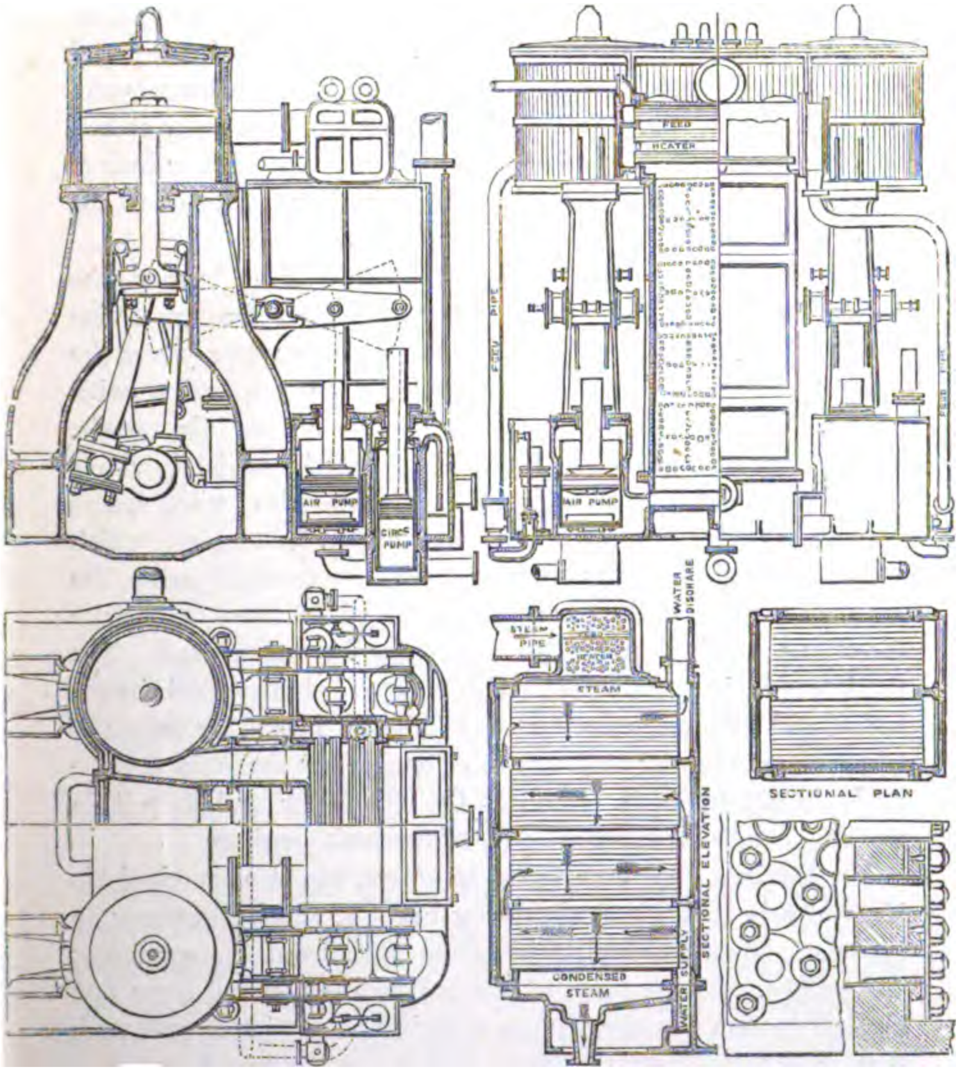
The first example we direct attention to is by Mr. Macnab, and was arranged by him in the year 1866, as illustrated by Fig. 72, which consists of six different views. The end and side sectional elevations with the half-complete view are at the top, and below is the plan half in section and complete, with a side sectional elevation and plan of the condenser, and a detailed view of the tube packing.

The surface condenser is in this case a rectangular structure, represented in transverse vertical and horizontal sections; it is provided with horizontal tubes arranged transversely in groups, for the passage of the condensing water, and is placed at one side of the cylinders and midway between them longitudinally as close as possible.

There are two air pumps, also two circulating pumps for forcing the sea-water current through the condenser tubes; an air pump and a circulating pump being placed on each side of the condenser. These pumps are single-acting, their buckets having trunks, acting vertically, being worked by beams or levers actuated by the piston rod, cross heads, and cross pins. One beam or double lever on each side works two pumps, and is also provided with pins for working a feed and bilge pump.

The condensed steam flows to the air pumps by channels formed in the bottom of the condenser. The air pump bucket does not rise to the top of its barrel; therefore a little water is always retained above it to keep it tight whilst the discharge takes place into the hot well, which is open to the atmosphere, and from which the feed pump takes the supply for the boiler.

FIG. 72.



Macnab's Arrangement of Surface Condenser and Pumps for Inverted Vertical Direct-Acting Screw Engines, patented in the year 1860.

Practical means are shown for imparting additional heat to the feed water prior to its entering the boilers, in this way: the two feed pipes are carried up to a casing, forming the top of the main condenser casing, which is provided with horizontal tubes that are arranged at right angles to the main condenser tubes. The feed water circulates by directing partitions in the end spaces, thereby causing it to traverse these tubes backwards and forwards, for the purpose of taking up heat from the new steam, which crosses the tubes on its way into the main condenser casing. The feed water passes on to the boiler by pipes connected to the casing, as shown in the elevation and plan.

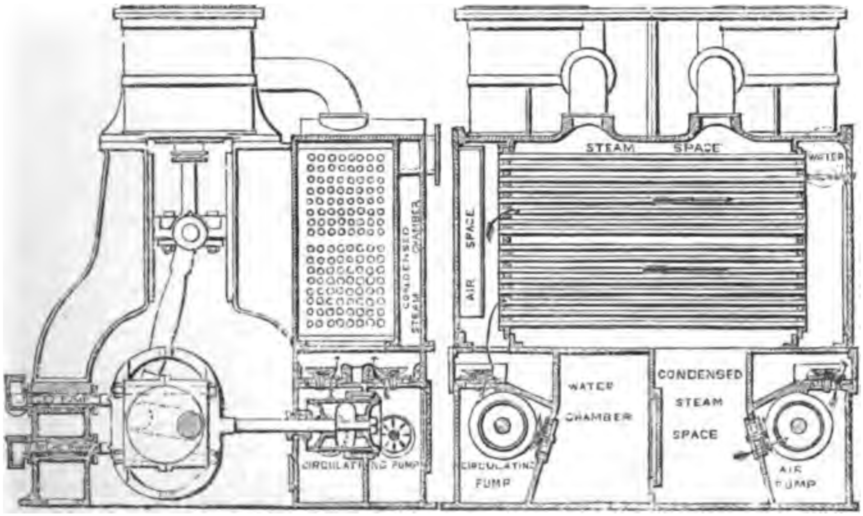
Each circulating pump is placed outside of or beyond the respective air pump, and receives the sea water through a pipe communicating with the vessel's side. The sea water enters the condenser from the pumps by passages, in connection with spaces, that are formed in the pumps, to act as air vessels. Valves may be applied in those passages or immediately above the pumps. The passages communicate also with spaces between the tube plates and covers of the condenser, which spaces are separated by directing partitions, which cause the currents to traverse the successive groups of the tubes in opposite directions, finally leaving the condenser by the outlets. The condenser is further provided with a flanged duplex inlet for sea water, and with an outlet for the condensed steam, by means of which the donkey or auxiliary feed engine of the ship may be made to act upon or clear out the condenser, and keep it in working condition independently of the main engines.

Mr. Davison, that we referred to before, has also exercised his ideas in this direction as shown by Fig. 73, which illustrates in elevation, transverse and longitudinal sections of the condenser and pumps. In the place of the ordinary piston rod lever and vertical motion for the pumps, a horizontal motion is preferred, that is derived from an eccentric fixed on the crank, and thus the stroke is one-half of that of the engine piston. By this arrangement the air and circulating pumps are on one side, and those for the feed and bilge on the other, of the crank shaft.

The circulating water is forced direct through the tubes, while the steam is condensed around them, making thereby a simple and accessible arrangement.

Mr. Davison also extended his powers of invention to the cleaning of the outsides of the tubes by a moveable perforated plate, which could be shifted forward and backward so as to *scrape* them. We should have illustrated it, were it not evident to any engineer that the method becomes useless from the fact, that if the plate fitted properly it could not be moved readily; and if it did not fit the upper half of each tube only would be scraped.

Fig. 73.



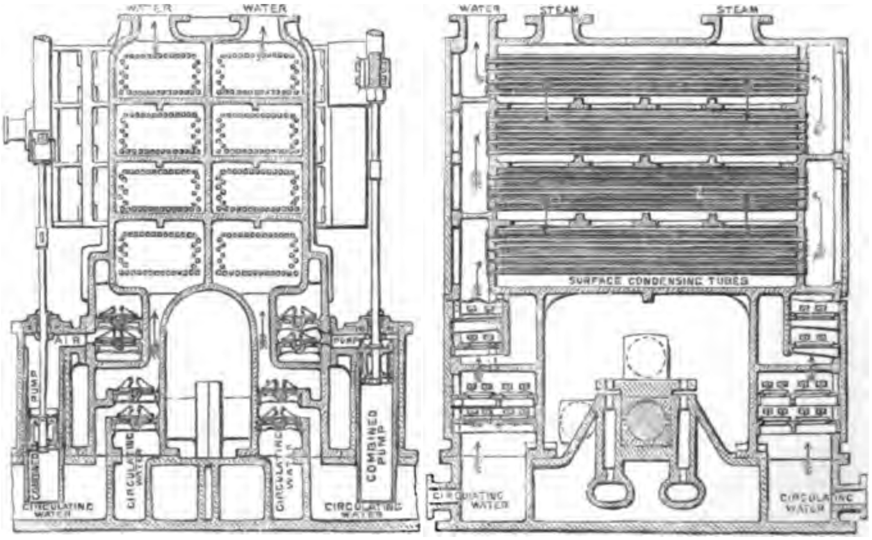
Davison's Arrangement of Surface Condenser and Pumps for Inverted Vertical Direct-Acting Screw Engines, patented in the year 1861.

In the year 1862 Mr. John Frederick Spencer, the well-known advocate of surface condensation, patented his arrangement as illustrated by Fig. 74, on the next page, which represents two inverted steam cylinders, resting on, and attached to a central surface condenser, and four wrought-iron columns, the columns and condenser also resting on, and being attached to the sole plate of the entire arrangement.

The main piston rods are secured above to the main piston in the usual way, and below, as shown, to the cross head, which latter has in its centre the necessary gudgeons for the upper joint of the main connecting rod. The cross head is extended each way to receive the bucket and plunger rods of two combined air and circulating water pumps, one feed pump, and one bilge pump.

The main piston rods and cross head are guided by two wrought-iron guide blocks, attached to the cross head, and working on the cast-iron guide frame, which latter is bolted to

FIG. 74.



Spencer's Arrangement of Surface Condenser and Pumps for Inverted Vertical Direct-Acting Screw Engines, patented in the year 1862, constructed in the year 1868.

	ft.	in.		
Diameter of Engine Cylinders .	0	68	Area of Air Suction Valves . .	56·25 sq. in.
Stroke of Piston	3	6	Lift of Valve	1½ in.
Number of Tubes, 1592 . .			Lift for Discharge	2½ „
Outside Diameter of Tubes .	0	1	One Set of Circulating Suction Valves, 4	
Length of Tubular Surface .	7	8	Area of ditto	117 sq. in.
Diameter of Combined Pump for Air and Circulation .	0	12	Lift of Suction Valves . . .	1½ in.
One Set of Air Suction Valves, 2			Lift of Discharge Valves . .	2½ „

the surface condenser ; thus the whole thrust of the connecting rod is taken by the main framing of the engines.

The combined air and circulating water pumps are secured to the sole plate by flanges and bolts as usual, and in such a position as to keep the top of the pump barrel nearly or quite below the bottom of the condenser. The upper portions of the combined pumps act as the air pump, and each air pump has its own set of inlet and delivery valves. The hot wells are on one side only of the crank shaft, and are contained in the two hollow cast-iron legs that support one end or side of the surface condenser, there being four of such legs forming the support and attachment to the sole plate. The air pump on one side delivers the air and condensed water through the passage across the crank shaft into the hot well on the other side. The circulating water pumps are formed by the lower or bottom portion of the combined pumps, and there is only one set of valves to the two pumps attached to the same cross head, and these valves are in the respective legs of the surface condenser, occupying a similar position to the hot well in the other side. Two sets of these valves, with combined pump barrels and part of the sole plate, are shown in section with the delivery passage leading to the condenser tubes and inlet passage for the circulating water to pass through the tubes.

The daring deeds and hair-breadth escapes of the S. S. " Alabama," N. A., are of course as vivid as ever in the political world, and to be connected with that ship honourably, in any way, claims popularity. Such becomes the firm of Messrs. Watt, who constructed the boilers and engines of the steam-yacht " Deerhound," that saved the captain of the " Alabama " when she sank, after her last naval war engagement.

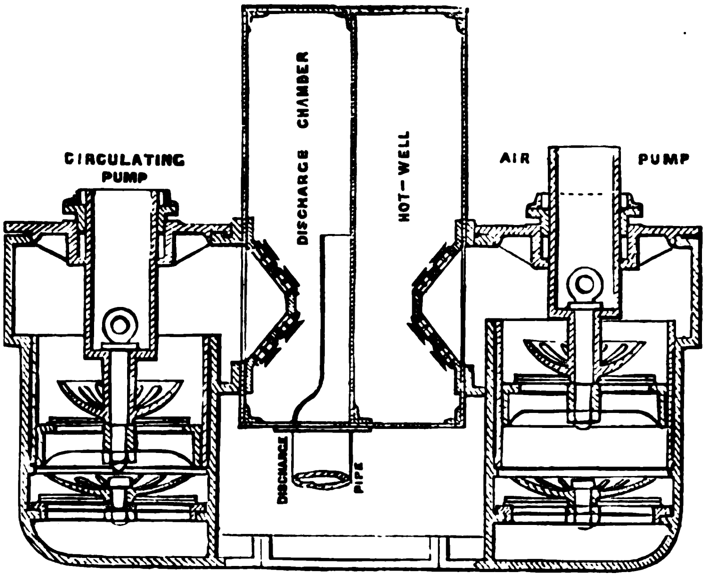
The pumps and water tank are illustrated in sectional elevation by Fig. 75, on the next page, and show a very convenient and duplicate arrangement: the pistons receive their motion from two levers, worked from the cross heads of the piston rods of the inverted vertical screw engines that drive the screw propeller.

The condenser is of simple construction and arrangement, as illustrated by Fig. 76, on the next page. The casing is of copper, made cylindrical, with the steam surrounding the tubes, and the circulating water passing through three groups or sets of them, as shown by the arrows of indication.

To understand the relation of the two preceding views, the illustration, Fig. 77, on page 79, is introduced, which represents the plan of the condenser, pumps, and pipes, and shows their position in the hull when in working order.

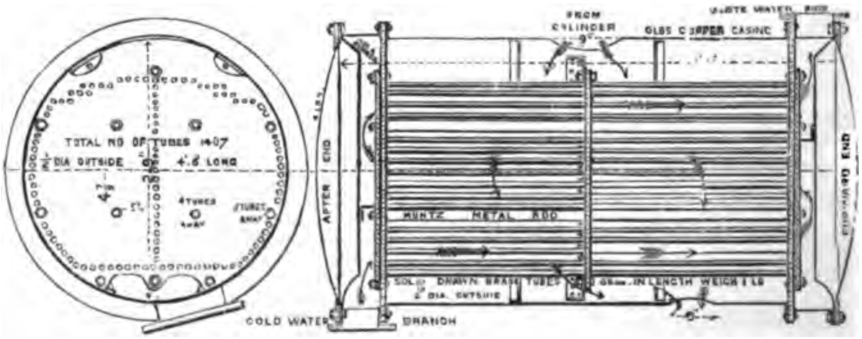
Our last illustration in this chapter is represented by Fig. 78, which is an end sectional elevation of the air pump and condenser on the left hand, and on the right a side or front sectional view of the condenser and valves, as fitted by the late

Fig. 75.



Watt's Arrangement of the Air and Circulating Pumps and Water-Tank for Inverted Vertical Direct-Acting Screw Engines, fitted in the S. Y. "Deerhound" in the year 1864.

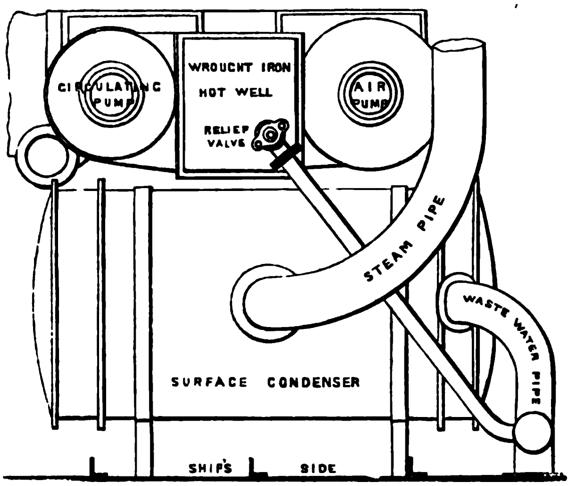
Fig. 76.



Watt's Arrangement of the Condenser for Inverted Screw Engines, fitted in the S. Y. "Deerhound" in the year 1864.

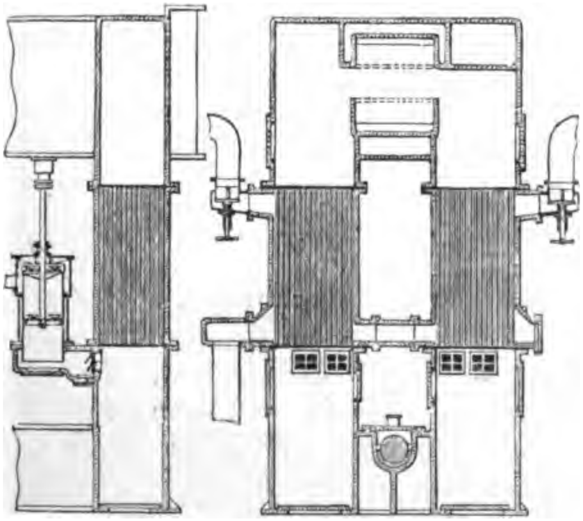
Mr. E. Humphrys, in two Indian steamers, where he faithfully carried out "Hall's" system, by arranging that the steam should pass direct *through vertical* tubes, and the circulating water pass around them; which was caused in this case by a centrifugal pump driven by a separate engine.

FIG. 77.



Watt's Arrangement of the Surface Condenser, Pumps, and Pipes for Inverted Vertical Engines, fitted in the S. Y. "Deerhound" in the year 1864.

FIG. 78.



Humphrys's Arrangement of Surface Condenser and Pumps for Inverted Vertical Direct-Acting Screw Engines, constructed in the year 1861.

CHAPTER IX.

SURFACE CONDENSERS FOR HORIZONTAL DIRECT-ACTING SCREW-PROPELLER ENGINES, PRACTICALLY CONSIDERED.

With engines of this class, the engineer has free scope to exercise his talents for practical and effectual designing, because the cranked shaft, connecting and piston rods, and cylinders are situated opposite the condensers, or—as may be expressed—"away from them."

The arrangement of the tubes can be either vertical, horizontal, or angular; the first applies to circular condensers chiefly, and the two latter to square or rectangular shells; but in any case the allotted room in the hull will settle—to a great extent—the position of the tubes.

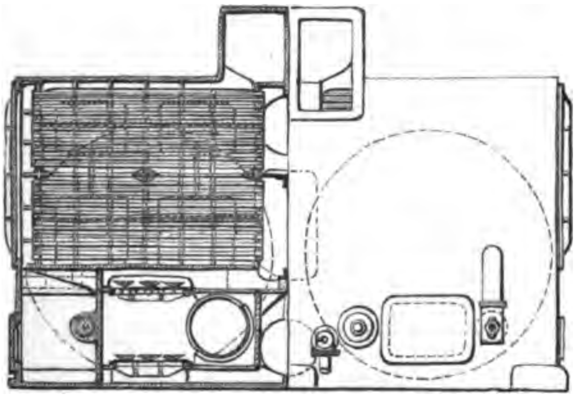
About ten years ago the marine-engine contractors for our Government were "called upon" to fit surface condensers with their engines; and the lead was taken by Messrs. Penn for the direct-acting class. This is illustrated by Fig. 79 on the next page, in transverse sectional and complete views.

The tubes are horizontally arranged, above the pumps, the steam surrounding them within the compartment; the pumps being near the centre of the arrangement. The suction valves are below the barrel, at the side, and those for the discharge are directly above. The passage for the circulating water is thus. On the water entering at the central back opening, it is forced—by the pump's piston—through the central end of the first tier of tubes, and on reaching the opposite extremity it rises and enters the top set; the final discharge being through the upper opening at the back end of the structure.

The exhaust steam enters the compartment at the front end, and after being condensed, falls to where the air pump suction valves are inverted. The discharge valves are also on the same level, the discharge chamber being at the side of the pumps.

It will be noticed that *only two* pumps are shown in the illustration, although both circulating and air pumps are requisite for each condenser. This is effected by using one end of each pump for circulating, and that opposite for the discharge of the condensed steam. Each pump is therefore single acting, for the separate duties, but double acting in arrangement.

FIG. 79.



Penn's Arrangement of Surface Condensers for Horizontal Double-Trunk Screw Engines, introduced in the year 1860.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 500			Diameter of Suction Valves (air pump)	0	8½
Inside diameter of Tubes . .	0	0⅞			
Outside ditto . . .	0	1	One set of Suction Valves (5)		
Length of Tubes between Plates	6	6½	Diameter of ditto (circulating pump) . . .	0	8¾
Number of ditto (4,832)					
Diameter of Pumps (2) . .	1	8	One set of Suction Valves (15)		
Length of Stroke	3	6	Diameter of Supply Water Pipe	1	8
Diameter of Pump Rod . . .	0	3	Diameter of Discharge ditto	1	8

The pistons of the pumps are the ordinary disc kind, and the rods are connected directly to the trunk pistons of the engines. The condenser compartments are accessible by the removal of the doors—suitably arranged; while the tubes can be readily cleansed internally, or renewed when requisite.

The relative position of the tubes with the line of keel is parallel with the same—the access for cleansing and repairs being, therefore, fore and aft of the condensers.

But Messrs. Penn did not confine their ideas of arrangement to the example illustrated. In some instances they adopt a vertical position for the tubes. The condensers are cylindrical, the tubes being concentrically arranged—to form a space, centrally, for the admission of the exhaust steam pipe. This latter detail is perforated at the extremity by parallel openings to ensure a ready distribution. The steam surrounds the tubes while the water flows through the same—suitable compartments being formed above and below the plates.

The air pumps are double acting, situated between the condensers: the suction and discharge valves being under and over the barrels. The circulation of the water is effected by centrifugal pumps and separate engines.

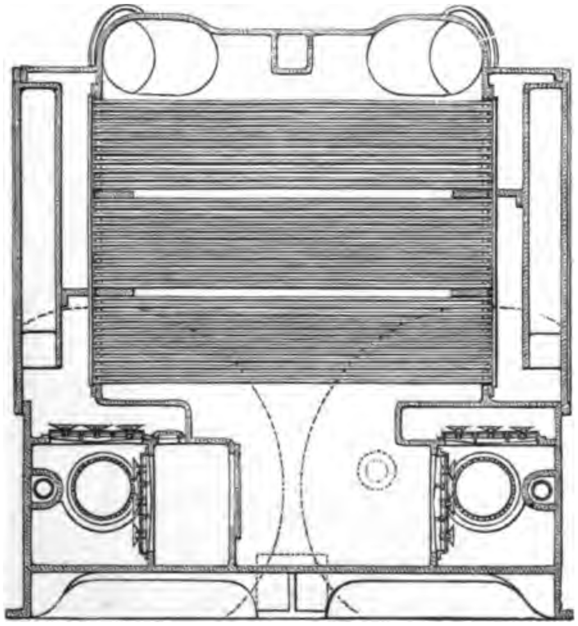
This firm have also used the arrangement shown by Fig. 53, on page 54, which has now become universal, and is really the best of its class yet in practice.

A novel arrangement for the valves and tubes is shown in transverse sectional elevation by Fig. 80, and in side sectional elevation by Fig. 81, on page 84. This was constructed by Messrs. Dudgeon in the year 1865. The circulating pump is on the left-hand side, and the air pump on the right. The tubes are horizontally situated above the pump, in three clusters. The traverse of the water is *through* the tubes, and its circuit is thus: The vertical valves—suction—admit the water into the pump, and those for the discharge—horizontally situated—allow the flow into the *first* set of tubes. After the water has passed through to the other extremity, it rises to the *second* set, and from thence through the *third* set—the final discharge being at the top of the compartment, at the back end. It is, perhaps, needful to add, that the supply and discharge pipes are fore and aft of the arrangement.

It will be noticed that two divisional ribs are secured, on the tube plate, between the corresponding sets of tubes, to cause the forward and backward circuit alluded to; and at each end of the tubes air chambers are formed, and thus the action of the pump is accelerated. The exhaust steam enters the tube compartment at the front end, above the tubes.

The air pump valves are similarly situated as those for the circulating pump. The action, therefore, being alike with each, the final discharge is effected at the back of the tube chamber.

FIG. 80.



Dudgeon's Arrangement of Surface Condensers for Horizontal Direct-Acting Screw Engines, introduced in the year 1865.

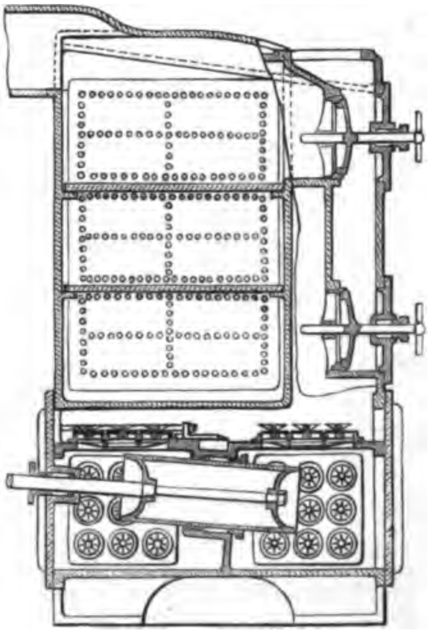
Nominal H.P. of Engines, 175.

	ft.	in.		ft.	in.
Inside diameter of Tubes	0	0½	Diameter of Pump Rod (circulating)	0	2¼
Outside ditto	0	0⅝	Diameter of Suction Valves (air pump)	0	5
Length between Plates	5	1½	Number of Suction Valves (9)		
Number of Tubes (1,998)			Diameter of Discharge Valves. .	0	5
Diameter of Air Pump	0	11	Ditto ditto (circulating pump)	0	5
Diameter of Circulating Pump . .	0	11	Diameter of Supply Water Pipe .	0	9
Length of Stroke	2	0	Diameter of Discharge Water Pipe	1	0
Diameter of Pump Rod (air) . .	0	2¼			

Messrs. Watt doubtless led the way for Messrs. Dudgeon, by the arrangement shown by Fig. 82, on page 85, which is very similar to the one above, excepting that in this case Messrs. Watt used two pumps of each kind for the circulating water and the condensed steam, while the other firm used only one for each purpose.

We may add that both firms carefully designed and arranged valves to change the duty of the circulating pumps when the condensers were worked on the injection system.

FIG. 81.

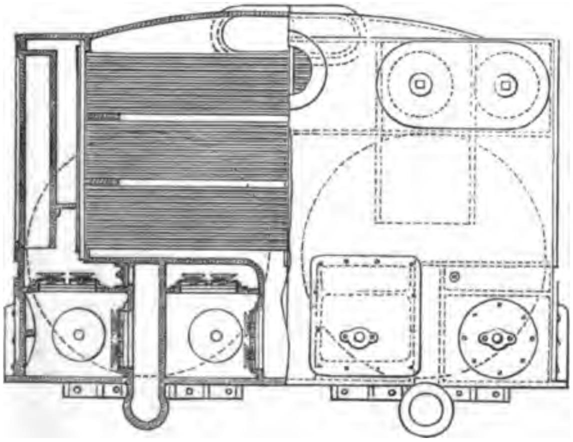


Dudgeon's Arrangement of Surface Condensers for Horizontal Direct-Acting Screw Engines, constructed in the year 1865.

We next direct attention to an arrangement of surface condensers by ourselves, which we carried out in the year 1862, as illustrated by Fig. 83, on page 86.

The tubes are secured at an angle above the air and circulating pumps. The exhaust steam enters the compartment *between* the inner tube plates, and passes—right and left—*through* the tubes. The air pump—of the lesser diameter—drains the compartment at the outer extremities of the tubes, and thus a continuous and almost direct current is effected. The suction and discharge valves are above the pump on the same level—the passage above the latter communicates with a tank—thereby a free action is maintained. The circulating pump—of the greater diameter—is at the side of the air pump, both suction and discharge valves being similarly situated for each purpose. The circulating water enters through the oval opening at the back, and, after passing amongst the tubes, it is discharged through the pipes at the top of the compartments.

FIG. 82.



Watt's Arrangement of Surface Condenser for Horizontal Direct-Acting Screw Engines, constructed in the year 1860.

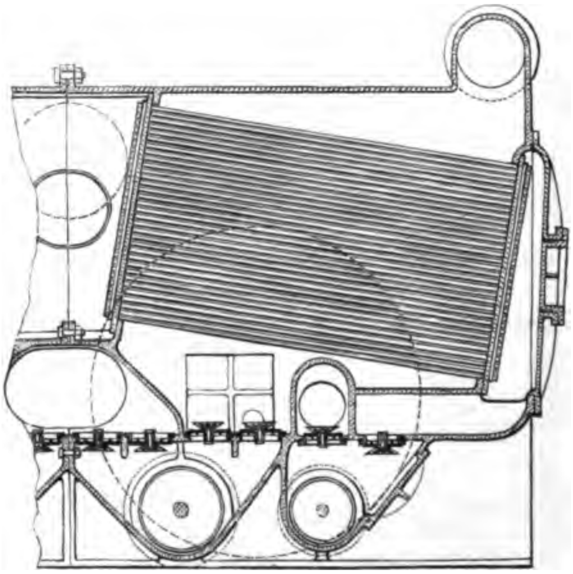
Nominal H.P Engines, 200.

	ft.	in.		ft.	in.
Inside Diameter of Tubes	0	$0\frac{3}{8}\frac{1}{32}$	Diameter of Pump Rod (Circulating)	0	$2\frac{3}{8}$
Outside ditto	0	$0\frac{1}{2}$			
Length between Plates	7	1	Diameter of Suction Valves	0	$5\frac{1}{2}$
Number of Tubes (2506)			Diameter of Discharge ditto	0	$5\frac{1}{2}$
Diameter of Air-Pumps (2)	0	10	One set of each (6)		
Diameter of Circulating Pumps (2)	0	10	Diameter of Supply Water Pipes (2)	0	$6\frac{1}{2}$
Length of Stroke	2	0	Diameter of Main Discharge Pipe	0	10
Diameter of Pump Rod (Air)	0	$2\frac{3}{8}$			

The main effect attained with this arrangement is a duplication of the entire working details for each engine—with single pipes for the supply water and exhaust steam, common to both engines. By this a saving of connections results, and in the weight of material and space occupied in the hull.

The doors for access to the several compartments are all suitably arranged, and on the main or large doors those of a small size are secured; the removal of which being for inspection only. It is worthy of remark, that even by a reverse situation for the pumps and the steam *surrounding* the tubes, the arrangement will be but little affected—at least the tubes can remain as illustrated; the circulating water entering at the top of the central compartment, and the condensed steam being discharged through the central opening below, with the valves reversed also.

FIG. 83.



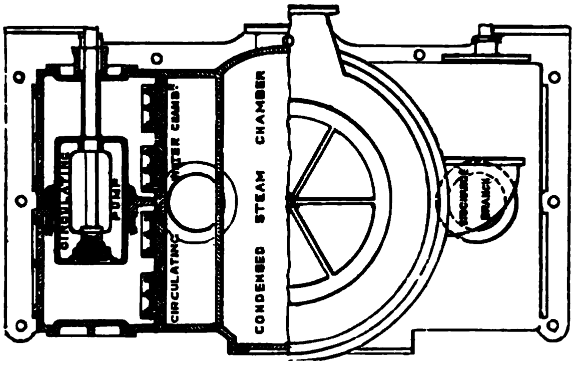
Burgh's Arrangement of Surface Condensers for Horizontal Direct-Acting Screw Engines, introduced in the year 1862.

	ft.	in.
Nominal H.P. of Engines, 200		
Inside diameter of Tubes .	0	$0\frac{5}{8}$
Outside ditto .	0	$0\frac{3}{4}$
Length	5	0
Number of Tubes (2494)		
Diameter of Air Pumps (2) .	0	10
Diameter of Circulating Pumps (2)	1	1
Length of Stroke	2	6
Diameter of Pump Rod (Air) .	0	$1\frac{1}{2}$
Ditto Ditto (circulating)	0	$2\frac{1}{4}$

	ft.	in.
Diameter of Suction Valves (Air Pump) . . .	0	6
One set of Ditto (4)		
Ditto Discharge Valves (4)		
Diameter of Suction Valves (Circulating Pump) .	0	$6\frac{1}{2}$
Number of Ditto (6)		
Ditto Ditto Discharge Valves (6)		
Diameter of Supply Water Pipe	1	5
Diameter of Discharge Pipes (2)	1	0

In the year 1867, we were called upon to design two pairs of twin screw engines, direct acting, with surface condensers of the cheapest and best arrangement then known. The arrangement we settled on is illustrated in plan, side elevation, and end elevation, in sectional and complete views, by Figs. 84, 85, and 86, where it will be seen that the shell of the tube-chamber is a cylinder with a discharge channel and branch pipe at the top, and above that is the cover—"dish shaped"—with the steam and injection branches. At the base plate of the tube compartment, are the air and circulating pumps, valves, and chambers, all duplicate in arrangement and size: the suction valves' seatings in each case are vertically secured at the sides of the pumps, and those for the discharge horizontally placed above. The action of this arrangement is thus: The steam enters the branch at the top, and then passes direct through the tubes into the chamber below, and is then, by the air pump, pumped, in the form of hot water, into the feed-tank. The circulating pump gets its supply from a chamber, formed under the lower tube plate, which has an opening in the bottom connected by a pipe to the sea water "Kingston Valve;" this pump therefore forces the water into the lower part of the tube chamber and through the discharge opening at the top, and from thence out at the ship's side, by which circuit the chamber is always full and a continual change of water occurs. When injection is used alone, the use of the circulating pump is not required, the air pump being sufficiently large for the purpose.

FIG. 84.



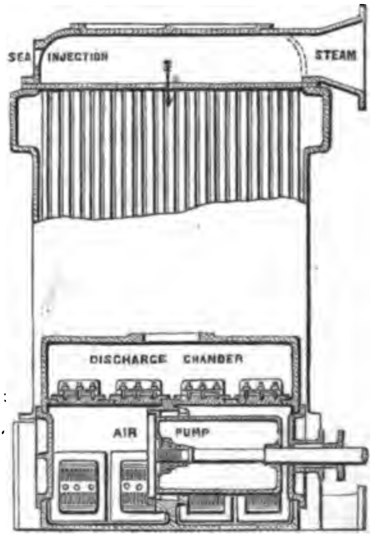
Plan of Burgh's Cylindrical Surface Condenser, with Duplicate Air and Circulating Pumps, for Horizontal Direct-Acting Screw Engines, as constructed in the year 1868.

We have lately carried out the same arrangement for outside surface condensation, as illustrated by Fig. 87, on the next page. In this case the tubes are arranged with a circular space in the centre, in which, at the top, is a perforated exhaust steam pipe; the perforations distribute the steam equally amongst the tubes as referred to on page 82; the pumps are duplicates in size, but the two sets of valves are arranged differently for their separate duties.

The circulating pump on the right hand receives its water through the top valve seating, the vertical valve permitting the discharge through the tubes; the final opening in the top cover over the tubes being shown by dotted circles.

The air pump receives the condensed steam by the way of the suction pipe and passage below the lower tube plate, and passes through the vertical valve seating, the discharge being effected through the seating over the pump, and thence into the feed tank, and from there by other pumps into the boiler.

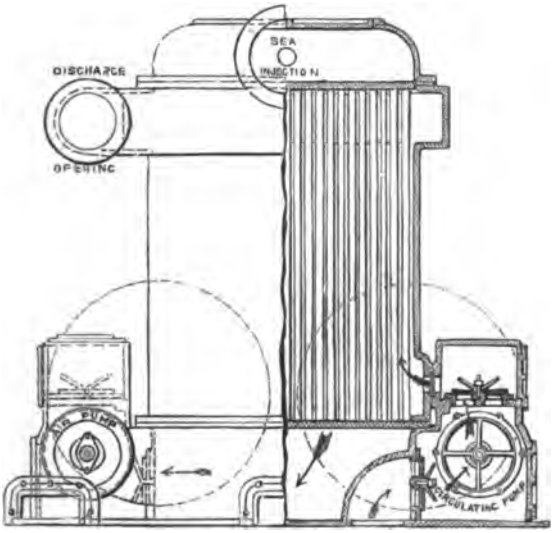
Fig. 85.



Elevation of Burgh's Cylindrical Surface Condenser, with Duplicate Air and Circulating Pumps, for Horizontal Direct-Acting Screw Engines, as constructed in the year 1868.

When the injection system is adopted, the circulating pump is disengaged and the air pump is in full use—the injection valve is on the top of the exhaust steam pipe not shown.

FIG. 86.

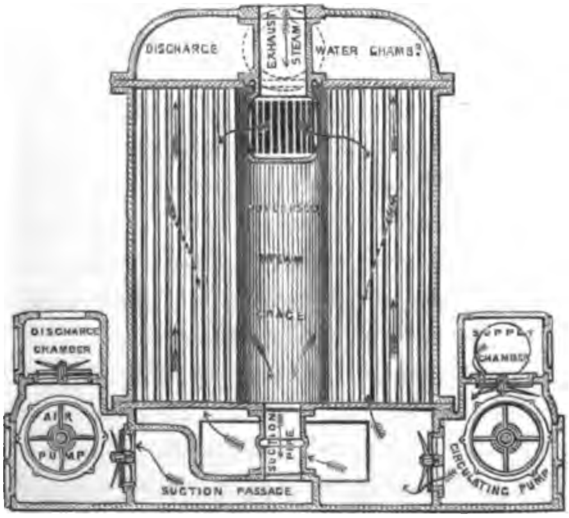


Elevation of Burgh's Cylindrical Surface Condenser, with Duplicate Air and Circulating Pumps, for Horizontal Direct-Acting Screw Engines, as constructed in the year 1868.

Nominal H.P. of Engines, 100	
Number of Tubes (1527)	
Inside diameter of Tubes .	11/16 in., bare
Outside ditto .	¾ „ full
Length of Tubular Surface	5 ft.
Diameter of Pumps . .	12⅝ in.

	ft.	in.
Diameter of Rods	0	2⅛
Stroke of Plunger	1	6
Area of 1 Set of Suction Valves	84 sq. in.	
Area of 1 Set of Discharge Valves	90 „	
Diameter of Circulating Pipe .	10 in.	
Diameter of Injection Pipe . .	3¼ „	

FIG. 87.



Sectional Elevation of Burgh's Cylindrical Surface Condenser and Pumps, for Horizontal Direct-Acting Screw Engines, as introduced in the year 1869.

CHAPTER X.

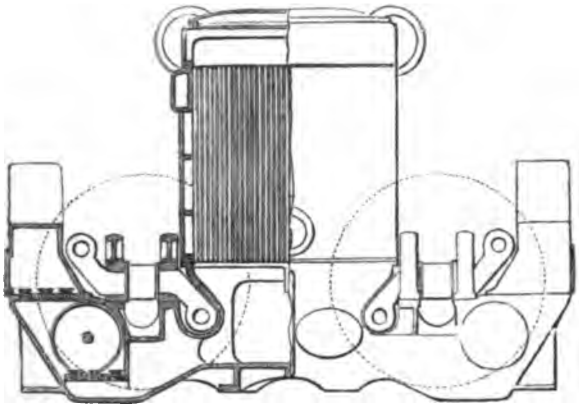
SURFACE CONDENSERS FOR HORIZONTAL RETURN-ACTION SCREW ENGINES, PRACTICALLY CONSIDERED.

WITH this class of engine the designing engineer has but little to choose from as to how he can best accommodate his ideas according to the facts before him; which are, that when the steam cylinders are to be so close together as possible, separate condensers beyond the outer piston rods are inevitable, with the tubes situated vertically or across the hull.

If the condenser is to be over the inner piston rods, then the vertical situation for the tubes can be allowed; but the steam cylinders must be proportionately separated apart. As to the latter case, the illustration, Fig. 88, is an example worthy of notice, as constructed by the firm of Messrs. Rennie, the engines being 350 horse-power nominal. Here the tubes are shown as stated, the steam passing through them, and the water surrounding their outsides. The left-hand pump is the air pump; and that half portion being in section, the applications of the details are apparent at once. The other pump is for the circulation of the water amongst the tubes, the water entering at the top and falling to the bottom of the compartment, and from thence discharged out at the ship's side.

Another arrangement is shown by Fig. 89. This is by Messrs. R. Napier and Sons. In this case the condenser is in the centre of the arrangement as before, but the tubes are horizontally secured across the engines above the inner piston rods: the steam surrounds the tubes and the water passes through them in three sets or groups, as in the example illustrated on page 83.

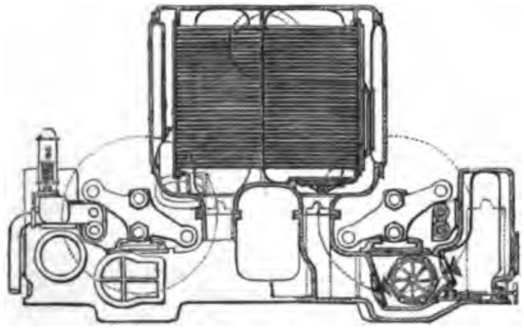
FIG. 88.



Rennie's Central Surface Condenser and Duplicate Pumps, for Horizontal Return-Action Screw Engines, constructed in the year 1865.

	ft.	in.		
Nominal H.P. of Engines, 350			Outside diameter of Tubes	$\frac{9}{16}$ in.
Diameter of Pump	1	9	Length	5 ft.
Stroke of Piston	3	0	Total Cooling Surface .	7000 sq. ft.

FIG. 89.



Napier's Central Surface Condenser and Duplicate Pumps for Horizontal Return-Action Screw Engines, constructed in the year 1866.

Nominal H.P. of Engines, 300.

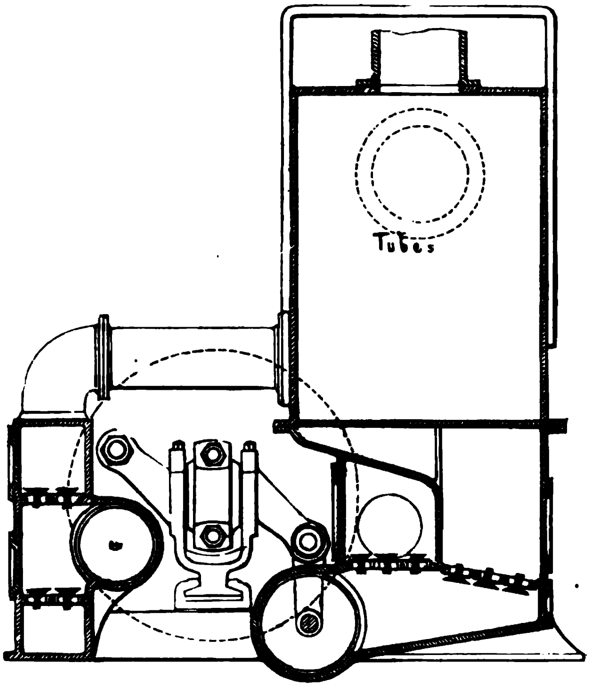
	ft.	in.			ft.	in.
Inside Diameter of Tubes .	0	$0\frac{5}{8}$ full.		Diameter of Pump Rod (Air) .	0	$2\frac{3}{4}$
Outside ditto . .	0	$0\frac{3}{4}$		Ditto ditto (Circulating)	0	$2\frac{3}{4}$
Length of Tubes between Plates	6	3		Sizes of Valve Gratings ($27\frac{1}{2} \times 5$ ins.)		
Number of Tubes (3923)				One set of Valves to each Pump (2)		
Diameter of Air Pump . .	1	4		Diameter of Supply Water Pipe.	1	4
Diameter of Circulating Pump	1	4		Diameter of Discharge Pipe .	1	4
Length of Stroke . . .	2	6				

Messrs. Napier, as ourselves, it will be seen, prefer in some cases a duplicate size and arrangement for the pumps and valves ;

and very neatly they have carried it out in this case, both for action and access; the valves being rectangular, with doors suitably placed to inspect and remove them.

When the condensers are used with the steam inside the tubes, and the compartment separate for each engine, or for one and half engine—as in the case of Maudslay's three cylinder engines—they are situated outside the outer steam piston rod, with the circulating pumps and chambers between the inner piston rods, as illustrated by Fig. 90, in transverse sectional elevation, and by Fig. 91, in longitudinal sectional elevation.

FIG. 90.

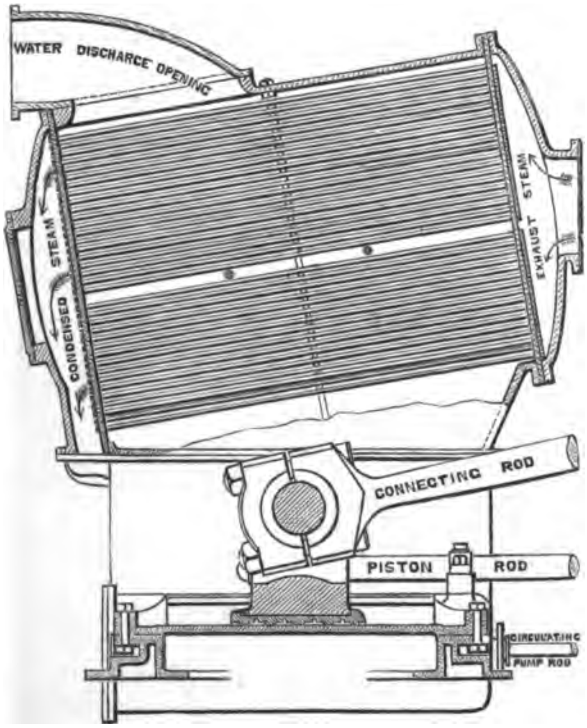


Maudslay's Outer Surface Condenser, with Angular Tubes and Separate Pumps, for Horizontal Return-Action Screw Engines, constructed in the year 1862.

The air pump is directly under the outer and lower steam piston rod, and is worked by an "arm" secured on the same; the suction valves, which are situated farthest on the right hand, are inverted to better drain the condenser; those for the discharge being directly at the side above the pump.

The circulating pump and its chambers are entirely separate from the condenser, and thus are simply arranged. The centre of the barrel is directly in a line below the inner steam piston rod; but the pump's piston receives its motion direct from the steam piston instead of from an arm, as in the other case. The suction and discharge valves are at the side, under and over the pump; the discharge into the condenser being through the pipe connecting the two chambers.

FIG. 91.



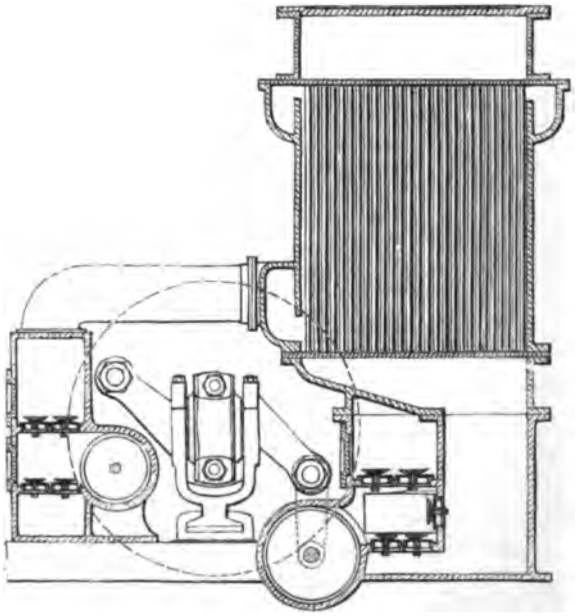
Maudslay's Outer Surface Condenser, with Angular Tubes and Separate Pumps, for Horizontal Return-Action Screw Engines, constructed in the year 1862.

	ft.	in.		ft.	in.
Nominal H.P. of Engines, 300.			Length of Stroke	2	6
Inside Diameter of Tubes . .	0	0½	Diameter of Pump Rod (Air)	0	2
Outside ditto . .	0	0⅝	Ditto ditto (Circulating)	0	1⅜
Length	6	5			
Number of Tubes (4872)			Diameter of Supply Water Pipes (2)	0	11½
Diameter of Air-Pumps (2) .	1	3⅞			
Diameter of Circulating Pumps (2)	0	10½	Diameter of Discharge Pipes (2)	1	2½

When Messrs. Maudslay have used vertical tubes with inside condensation they have carefully arranged the pumps as before; but then the suction valves have been altered a little, as illustrated by Fig. 92; but, excepting that, it is nearly a duplicate of Fig. 90, on page 92.

Messrs. Laird Brothers have had some practice in the difficulties attendant with the class of condensers under notice; and to overcome them prefer to adapt the arrangement, as shown by Fig. 93, on the next page, in two sectional elevations.

Fig. 92.



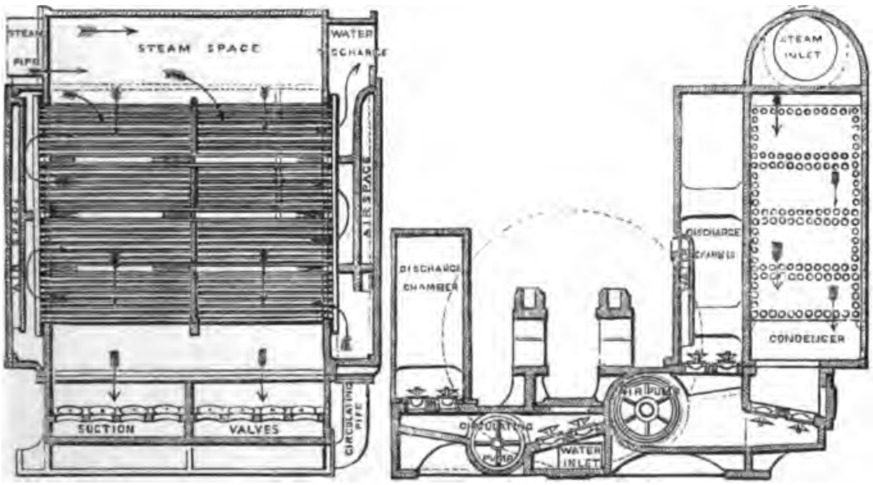
Maudslay's Outer Surface Condenser, with Vertical Tubes and Separate Pumps, or Horizontal Return-Action Screw Engines, constructed in the year 1862.

In this case it will be noticed that the condensing tube chamber is outside the piston rods—as in the two preceding examples—and the air pump and valves very similarly arranged also; but the piston is worked by the steam piston.

The circulating pump's piston receives its motion from an arm secured on the inner piston rod, and the suction valves are between the two pumps, while the discharge valves are at the side over their respective barrel.

The route of the circulating water from the inlet to the tubes is rather peculiar. It enters under the suction valves at the back of the arrangement, and after passing through the pump, and into the discharge chamber, it is, by a vertical pipe, at the back also, conveyed to the lower tier of tubes—as shown in the longitudinal view. It then passes and repasses through four sets of tubes, and finally out at the top, and thence through the pipe to the discharge valve connected to the ship's side.

FIG. 93.



Laird's Outer Surface Condenser, with Horizontal Tubes and Outside Condensation, for Horizontal Return-Action Screw Engines, constructed in the year 1866.

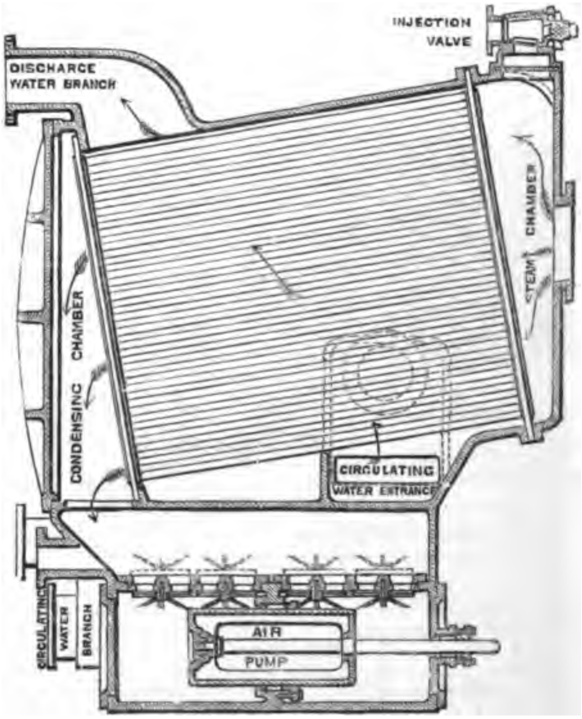
	ft.	in.		ft.	in.
Nominal H.P. of Engines, 200			Diameter of Discharge Valves.	0	6½
Number of Tubes (1116)			Diameter of Circulating Pump	0	11½
Inside Diameter of Tubes . .	0	0⅝ full	One Set of Suction Valves (8)		
Outside ditto . .	0	0¾ bare	Diameter of ditto . .	0	5¼
Length of Tubular Surface .	5	6	One Set of Discharge Valves (8)		
Diameter of Air Pump . .	1	1½	Diameter of ditto	0	5½
One Set of Suction Valves (8)			Stroke of Pumps	2	3
Diameter of ditto .	0	6	Diameter of Rods	0	2½ & 1½
One Set of Discharge Valves (8)			Diameter of Circulating Pipe .	0	9

Within the last six years we have had to design several return-action screw-engines with surface condensers, and the room in the hull allotted to us was very limited in nearly all the cases, but the most "pinching" of all happened in the year

1869, when we were allowed the least room, per indicated horse power, that ever fell to our lot. After practically considering the matter, we arranged the tubes as shown in the sectional view by Fig. 94, and the other details as illustrated by Fig. 95.

The main point in this was that we shaped the inner sides of the condensers to suit the angularity of the main crank connecting rods, and thus reduced the length of the arrangement on the "line of keel" of the hull, in which direction was our least allowance for "passage" room; and while thus shaping our condensers, we had also to keep the space between them sufficiently for access to inspect and repair all the intermediate details and chambers.

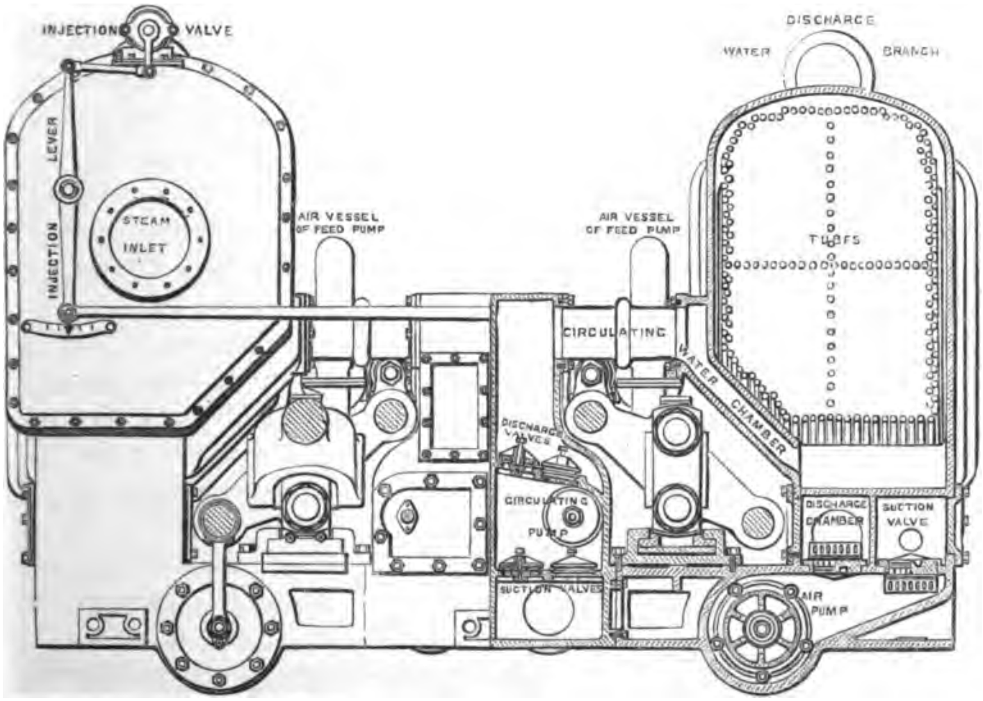
Fig. 94.



Longitudinal Sectional Elevation of Burgh's Angular Tube Under-Surface Condenser and Pumps for Horizontal Return-Action Screw Engines, constructed in the year 1869.

The arrangement of the pumps gave us much trouble also, both in their position and mode of working, but we overcame that by connecting the circulating pump rod direct with the engine piston, and the air pump rod with the outer piston rod by an arm for imparting their motions.

FIG. 95.



Front and Sectional Elevations of Burgh's Angular Tube Outer, Surface Condenser and Pumps for Horizontal Return-Action Screw-Engines, constructed in the year 1869.

Nominal H.P. of Engines, 100

Number of Tubes (each Condenser), 975		Diameter of Circulating Pump . .	7 in.
Inside diameter of Tubes . . .	$\frac{11}{16}$ in. bare	Area of 1 set of Suction Valves . .	38 sq. in.
Outside ditto . . .	$\frac{3}{4}$ „ full	Area of 1 set of Discharge Valves .	49 „
Length of Tubular Surface . .	4 ft. 6 in.	Stroke of Plungers	1 ft. 6 in.
Diameter of Air Pump . . .	10 in.	Diameter of Rods . . .	$1\frac{1}{2}$ in. and $1\frac{1}{4}$ in.
Area of 1 set of Suction Valves .	56 sq. in.	Diameter of Circulating Pipe. . . .	$6\frac{3}{4}$ „
Area of 1 set of Discharge Valves .	70 „	Diameter of Injection Pipe	3 „

The valves for the air pump are situated at its side over the same; those for the suction being inverted, and those for the discharge are on the same level, lifting upwards. The longitudinal section shows both sets of valves on the line of the pump's length—the suction valves being in section.

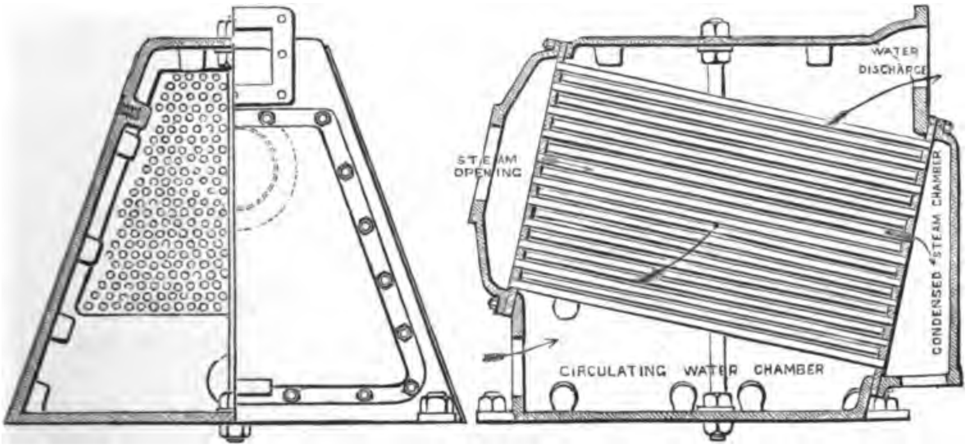
We preferred to use plungers in both cases, and rectangular valves for the air pumps, and metal valves packed with lignumvitæ for the circulating pumps.

The passage of the circulating water was peculiarly arranged, with the view of effect as well as compactness, by the water entering at the back end directly under the suction valves, which are under the pump, and those for the discharge above. The water when on those latter valves passed from their chamber through a pipe connecting it with the condenser, an angular passage being formed therein to convey the water amongst the tubes. The position of this water entrance opening under the tubes is shown in Fig. 94, on page 96, where is seen also that the water passed finally from the condenser through the discharge branch, at the top, at the back end. The passage of the condensed steam was direct through the tubes from the front to the back plate, and thence to the pump, as shown in that view also. When injection water was required, the plug valve at the top of the front cover, and its gear were used, and this was also applied slightly in conjunction with the surface condensation to keep up the full supply of feed water.

On page 49 there is illustrated an injection condenser and pumps for direct-acting inverted angular engines, and on this next page is illustrated, by Fig. 96, a surface condenser for the same class of engines. The tubes are angularly fitted for the condensed steam to drain through them, and the circulating water enters at the base of the compartment, and is discharged at the roof, at the opposite end. This example, although of a small size, is arranged to be suitable for any power; the cylinders in all cases being secured on the top of the condenser, and the guides and shafts at the sides. The pumps, double acting, were worked by an engine horizontally secured on one frame, and thus separate from the condenser and screw engines.

Another arrangement of a small condenser is shown by Fig. 97, the tubes being vertical, with the steam entering at the top, and passing through them to the bottom of the casing. The circulating water is forced amongst the tubes, by a centrifugal pump, from the bottom to the top of their chamber, and the condensed steam is forced into the boiler by the feed pumps. This condenser has been used with success in the Royal Navy in steam launches.

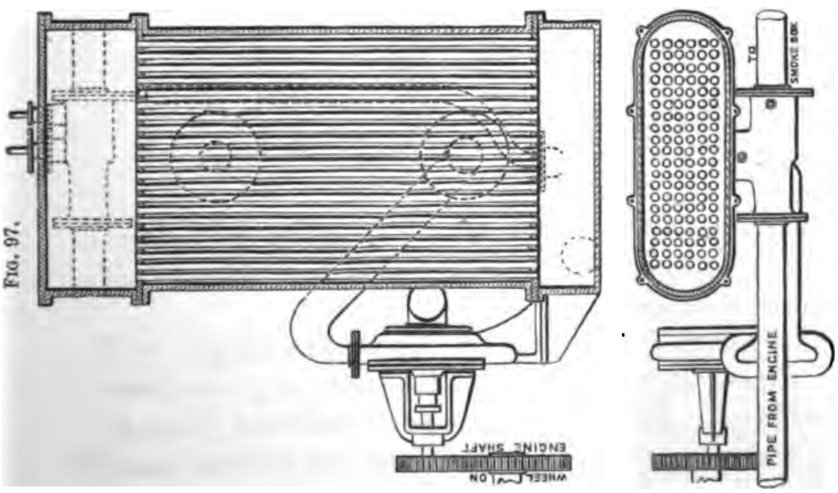
FIG. 96.



Burgh's Angular Tube Central, Surface Condenser for Angular Direct-Acting or Return-Action Screw Engines, constructed for, and fitted in, a Yacht in the year 1867.

Nominal H.P. of Engines, 10		Length of Tubes . . .	2 ft. 6 in.
Number of Tubes, 376		Diameter of Air Pump . .	4½ „
Outside Diameter of Tubes .	$\frac{9}{16}$ in.	Diameter of Circulating Pump	3½ „
Inside ditto . .	½ „	Stroke of ditto	5 „

FIG. 97.



Rennie's Surface Condenser and Centrifugal Circulating Pump for Yacht and Launch Engines, constructed in the year 1866. .

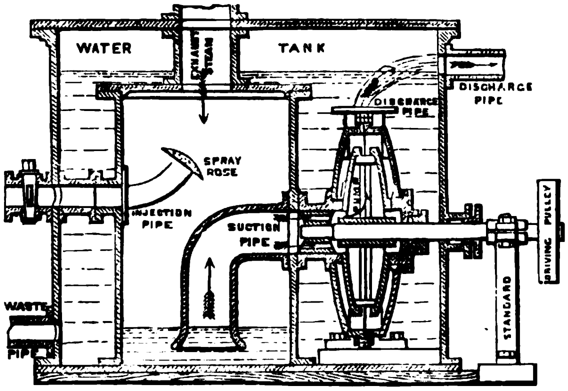
Nominal H.P. of Engines, 5		Outside Diameter of Tubes	$\frac{9}{16}$ in.
Number of Tubes, 86		Diameter of Centrifugal Pump	6 „
Length of Tubes. .	2 ft.		

CHAPTER XI.

ARRANGEMENT OF PUMPS AND VALVES FOR MARINE ENGINES: PRACTICALLY CONSIDERED.

Centrifugal Pumps.—An example of this class of pump is illustrated by Fig. 98, in combination with an injection condenser, which are submerged in a tank to ensure no leakage of air. This is a compact arrangement, and is applicable for land as well as marine engines.

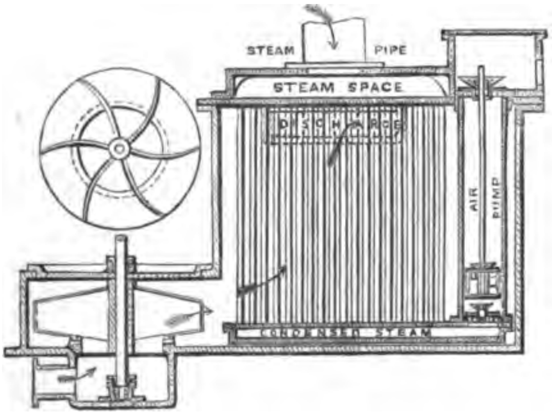
Fig. 98.



Gwynne's Centrifugal Pump and Injection Condenser for Marine Engines, patented in the year 1851.

Another example is shown by Fig. 99, as arranged by Mr. Henry Turner, eight years after the preceding arrangement was introduced. This was applied as a circulating pump for a surface condenser, the water entering at the bottom amongst the tubes, and discharged at the top of the chamber. The steam enters the space above the tubes, and passes through them to the space below, from where the air pump effects the continual draining necessary. This pump is worked vertically, the rod passing through a stuffing box, not shown, in the cover of the discharge valve casing.

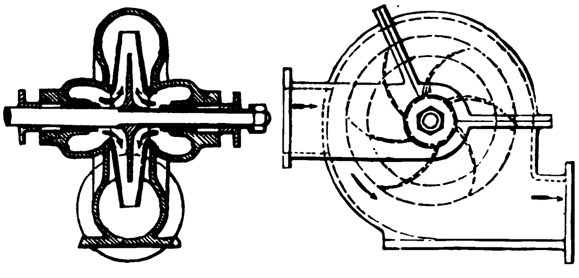
FIG. 99.



Turner's Arrangement of Centrifugal Circulating Pump, Vertical Air Pump, and Surface Condenser, for Marine Engines, patented in the year 1859.

The centrifugal pumps in both these cases are worked by separate engines from the marine engines, but in other cases spur gearing has been applied instead, driven from the main cranked shaft.

FIG 100.

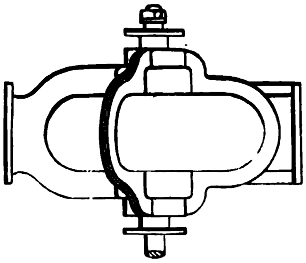


Modern Centrifugal Pump, used as a Circulating Pump for Surface Condensers of Marine Engines, constructed by all the leading firms since the year 1864.

We now refer to the most effectual design and modern centrifugal pump, as illustrated by Fig. 100, in sectional and complete elevations, and in complete plan by Fig. 101, on the next page.

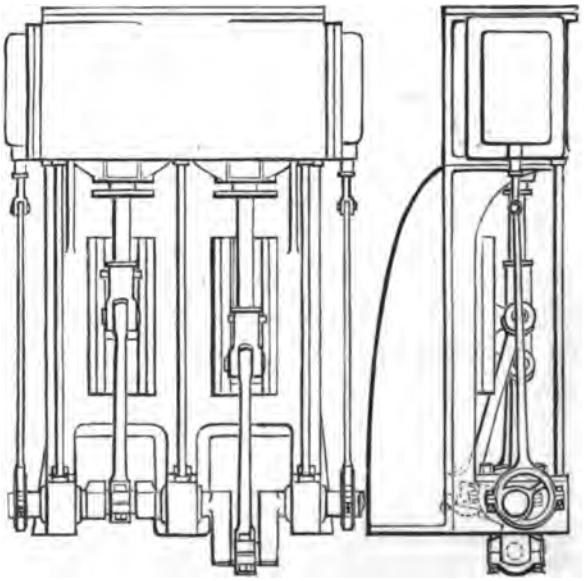
The mechanical connections are thus: The central or divisional plate of the fan is secured on the shaft by a key, and lateral disturbance is prevented by a bush secured on the end of the shaft by a nut, as seen in the sectional view. The shell is in two portions, connected by the angular and horizontal flanges, by which connection the fan can be removed easily without disturbing the lower portion or any branch connection.

FIG. 101.



Plan of the Pump shown by Fig. 100.

FIG. 102.

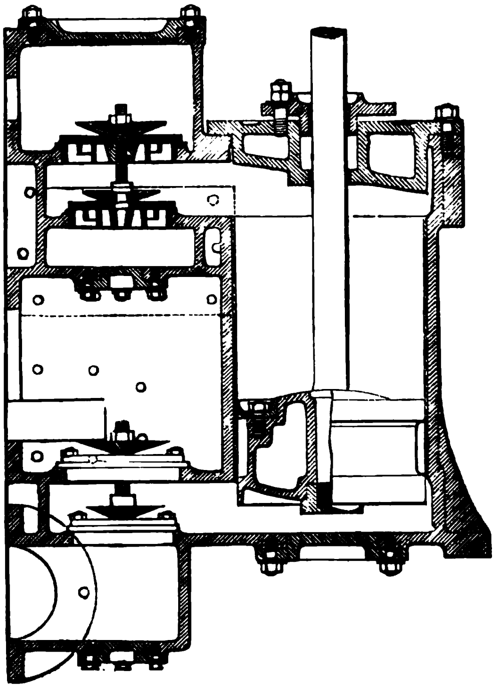


Modern Vertical Direct-Acting Engines, for driving the Fans of Circulating Pumps, as used since the year 1864.

	ft.	in.		ft.	in.
Diameter of Fan	2	0	Diameter of Steam Cylinders . .	0	8
Diameter of Divisional Plate . .	1	6	Length of Stroke of Piston . .	0	8
Diameter of Shaft	0	3	Width of Supply Port	0	0¾
Width of Casing at Centre. . .	0	5	Width of Exhaust Port . . .	0	1¼
Width at Edge.	0	2	Length of Ports	0	4
Radius of Internal Curve of Shell .	1	3	Length of Stroke of Slide Valve .	0	2¼
Diameter of Suction and Delivery Openings	0	9	Diameter of Piston Rod . . .	0	1¼
			Diameter of Slide Valve Rod . .	0	0¾
Height of Centre of Suction Opening from Base of Shell . .	1	6	Length of Connecting Rod. . .	1	4
			Diameter of Block Pin. . . .	0	1⅛
Extreme Length of Shell . . .	3	5	Thickness of Metal of Shell of Pump	0	0¾
Width of Shell at Suction Side .	1	7	Thickness of Metal of Steam Cylinders	0	0½
Width of Shell at Delivery Side .	1	3			

As the pump is useless without motive power to drive it, we illustrate, by Fig. 102, two elevations of two vertical direct-acting combined engines, as generally used now for that purpose. The slide valve is single ported, worked by a single eccentric and rod; the remaining visible portions explain themselves, and their proportions are given in the table under these illustrations, together with those for the pump illustrated by Figs. 100 and 101.

FIG. 103.

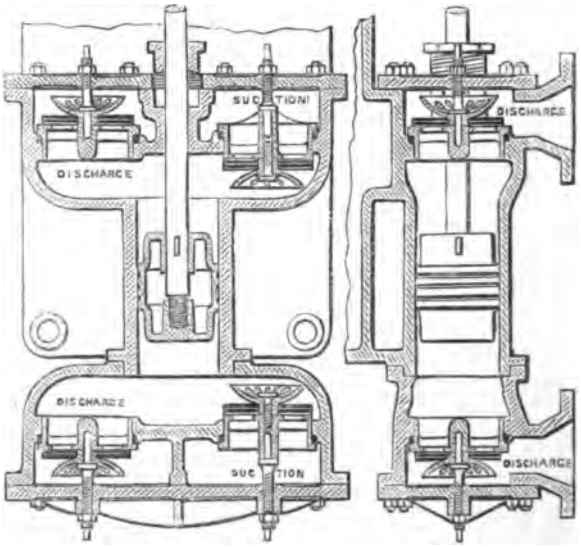


Spencer's Vertical Double-Acting Piston Pump, to be applied as an Air or Circulating Pump, separately, or combined at the same time, introduced in the year 1864.

DOUBLE-ACTING PISTON AND PLUNGER PUMPS.—An illustration of the first vertical double-acting air pump is shown on page 11 by Fig. 9, and although the first was a sound arrangement, taking into consideration that the valves were situated as near the ends of the barrel as their form admitted. Those were metal "clack" valves, it must be remembered; but when vulcanized india-rubber was introduced, a different form and arrangement of valves became possible, which led to the better method as illustrated by Fig. 103, on the preceding page, where the valves are directly over each other at the side of the pump, thus enabling the barrel to be the shortest length possible, proportionate to the stroke and depth of the piston.

The "side" position for the valves is not the best, however, and the knowledge of that fact induced ourselves to invent and patent the arrangement as shown by Fig. 104, where it is

FIG. 104.



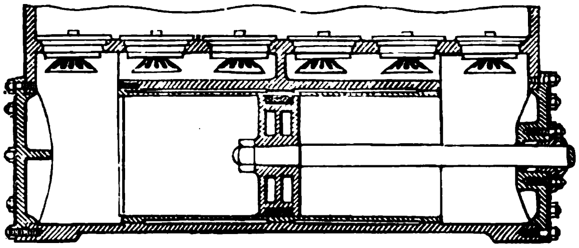
Burgh's Double-Acting Vertical Pump for Marine Engines, to be used as an Air Pump or Circulating Pump, separately, or combined at the same time, patented in the year 1869.

evident that a nearly perfect discharge occurs at each stroke of the piston, which is the proper attainment with all pumps, and which can only be carried out but by considering that the air in water always rises to the top when the fluid is compressed, and if the vapour does not escape *first* it remains in the pump to a considerable extent. Hence the need of an air vessel or its equivalent in bad arrangements; whereas in this one an air vessel is not required, because no air can remain in the pump, it being discharged before the water at each stroke of the piston.

The doors for access to inspect and renew the valves are directly over and under them, so that they can be easily removed with their seatings. It will be obvious also that the two top valves can be for air, and the two lower for water workings, at the same time if required, or *vice versâ*, or the four valves can be used for either purpose only.

When horizontal pumps are used, the arrangement depends a great deal on the class and power of the engines, as we have shown in the preceding chapters; but yet while considering that, the best acknowledged position for the valves must not be neglected, that is, the suction valves must be inverted and those for the discharge reversed, on the same level *over* the pump. An example of an ordinary piston pump of that class is illustrated by Fig. 105, in longitudinal sectional elevation, which shows the suction valves situated for the entire length of the casing, so that no space is lost lengthways, the discharge valves being on the same level.

FIG. 105.

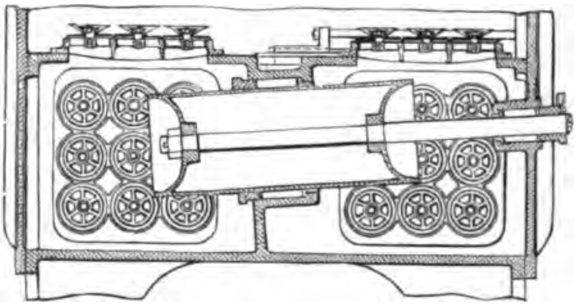


Longitudinal Sectional Elevation of a Modern Horizontal Double-Acting Piston Pump and Valves for Marine Engines, as used since the year 1862.

When the suction valves are required to be at the side of the pump, the illustration, Fig. 106, on the next page, represents the arrangement, which is the plunger type, but a piston could be used instead if desirable. This is a very effectual arrangement, and is now becoming general.

It is evident that when the suction and discharge valves are on the same level over the pump, they occupy a deal of space across the barrel, as seen in Chapter IV., and it sometimes occurs that that arrangement is not available, as for example, for the surface condenser shown by Fig. 86, on page 89, it would not apply, and a circumstance in connection with it originated the

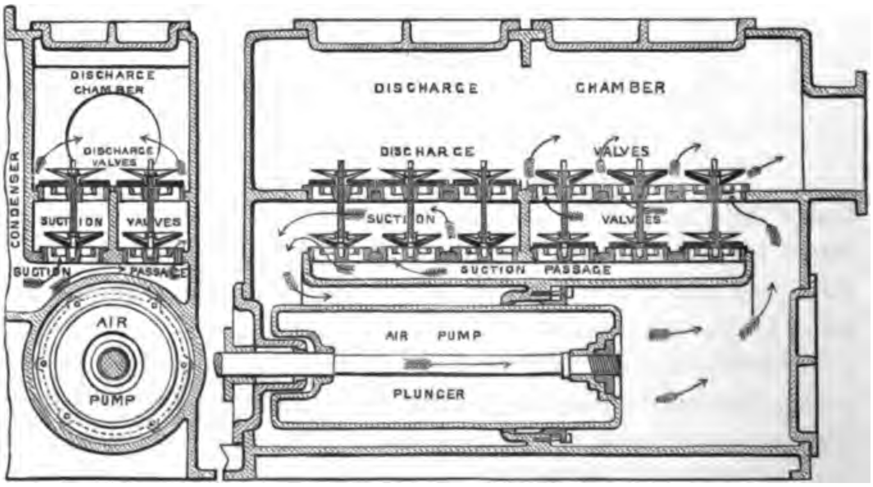
Fig. 106.



Longitudinal Sectional Elevation of a Modern Horizontal Double-Acting Plunger Pump and Valves for Marine Engines, used since the year 1864.

arrangement of valves shown by Fig. 107, where it is illustrated that the suction and discharge valves, although over the pump,

Fig. 107.

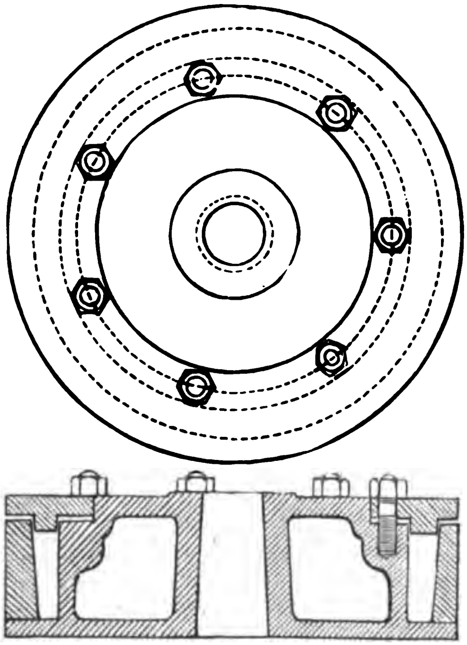


Burgh's Improved Arrangement of Valves for Horizontal Double-Acting Plunger Pumps for Condensers of Marine Engines, invented in the year 1870.

are secured within a space less than the diameter of the barrel; and as the two sets of valves are over each other, one door for each twin set is only required.

Treating next of the pistons of those pumps now under notice, we allude to the illustration, Fig. 108, which represents a section and plan of a metallic piston with spring and face rings for adjustment. The spring ring can be packed with india-rubber or any other suitable material: this is the present general practice by the leading marine engineers, when plungers are not preferred.

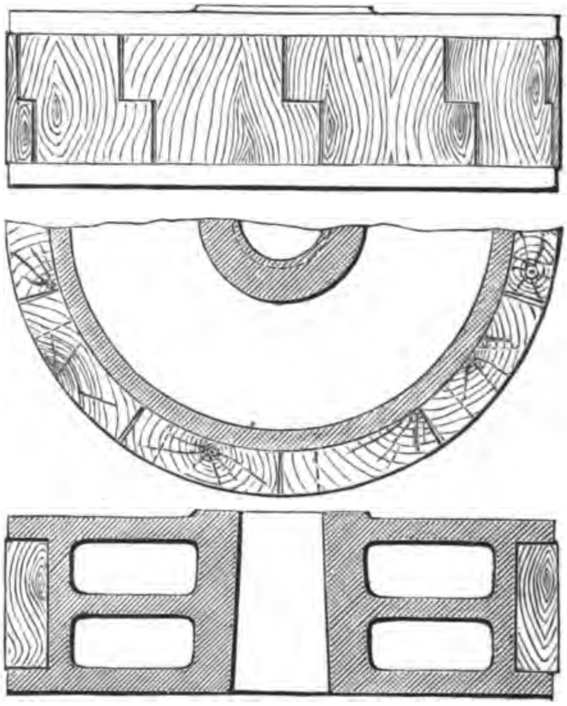
FIG. 108.



Metallic Piston for Air and Circulating Pumps, as used since the year 1857.

Messrs Maudslay, about ten years ago, introduced pistons for circulating pumps packed with lignum-vitæ, and we had occasion to use them also, as illustrated by Fig. 109, which is merely a metal grooved disc with blocks of the wood fitted in the groove. The only feature worthy of comment is the fitting of the blocks with each other, which is shown in the top view.

FIG. 109.



Burgh's Metal Piston packed with Lignum-Vitæ for Circulating Pumps, as used since the year 1860.

CHAPTER XII.

CONNECTIONS OF PUMP VALVES FOR MARINE ENGINES PRACTICALLY CONSIDERED.

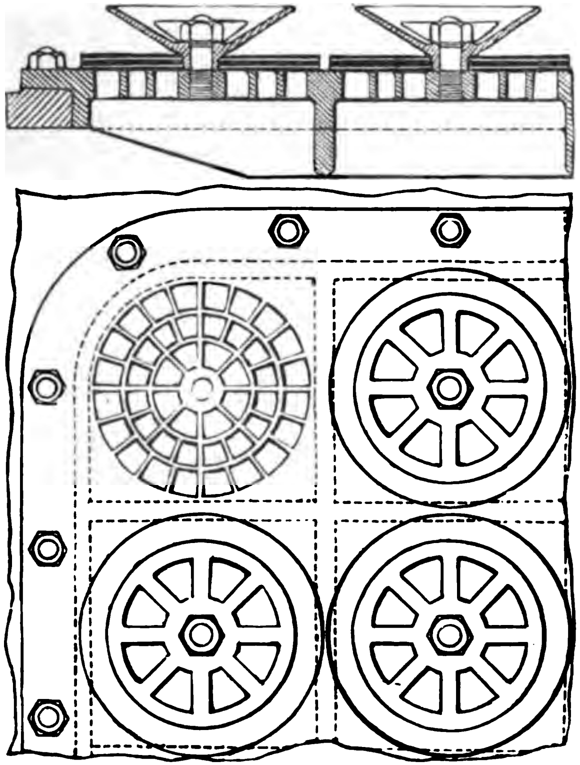
THERE is no detail of the condenser that has received so much attention, and undergone such a variety of changes, as the valves of the pumps, and when marine engines were first introduced, metal flap valves were used, as shown by Fig. 3, on page 7. Those valves of course made a loud noise, and wore very soon in their connection and faces.'

As the various requirements became apparent, they were met by suitable material in the form of india-rubber, which was introduced for pump valves about the year 1850.

Messrs. Penn were as early in the field to adopt it as any one, and they carried out the same mode of connection then as now, as illustrated by Fig. 110, on the next page, which shows that a seating plate of any suitable dimensions contains the requisite number of valves on it, and that one joint connection for the plate is only required. Each guard is secured by a stud and nut, and the guard surrounds the stud between the plate and the nut, while the valve encloses a portion of the guard.

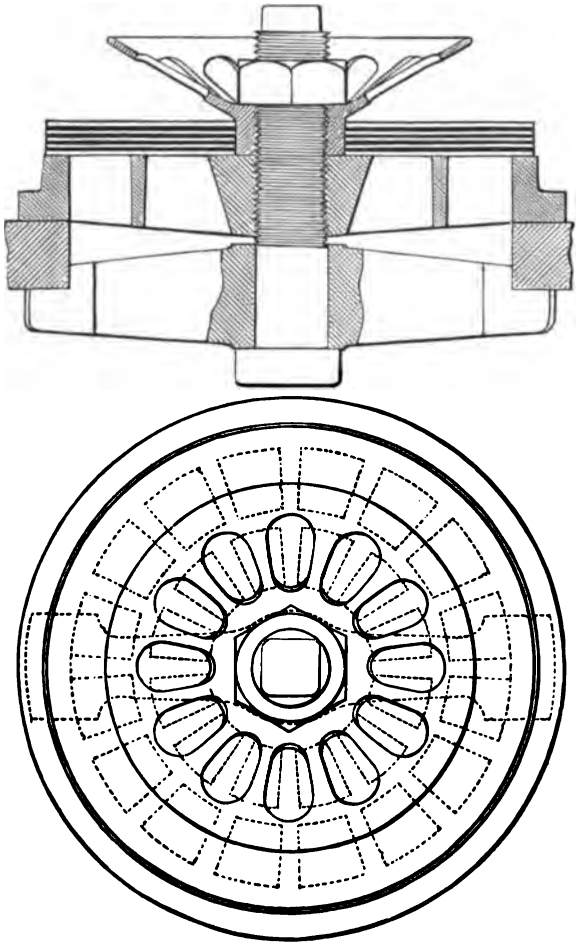
About the same date, 1850, Messrs Maudslay introduced their mode of connection, as illustrated by Fig. 111, which is a separate seating for each valve, the guard being as Messrs. Penn's, but the seating secured by a cross-bar on the opposite side of the projection on which the seating is jointed, and one bolt and nut completes the entire connection of the guard, valve,

FIG. 110.



Penn's India-rubber Circular Valves, Metal Guards, and Multivalvular Seating Plate, for the Pumps of Marine Engines, as used at the present time.

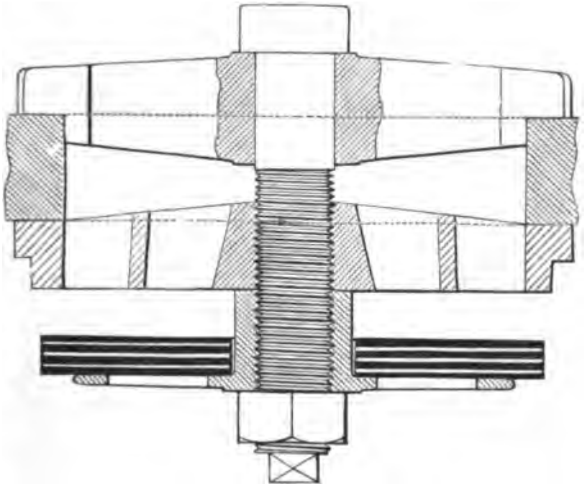
FIG. 111.



Maudslay's India-rubber Circular Valve, Metal Guard, and Single Seating, with Connecting Cross-Bar and Bolt, for the Pumps of Marine Engines, as used at the present time.

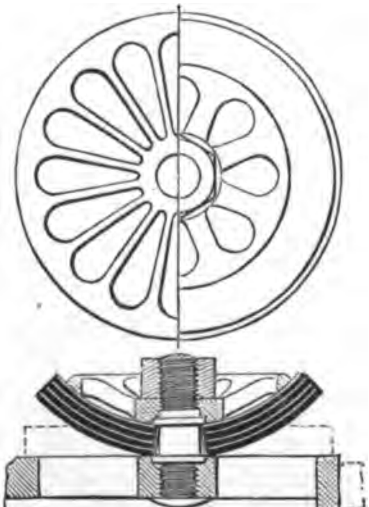
and seating. This has been used by the firm to the present time, and the practical advantages warrant its future continuance. Those advantages are equally applicable for inverted valves also, as illustrated by Fig. 112. In this case the guard is a flat disc, with a projection on it sufficiently deep for the valve to have a certain entire rise and fall in its action, or "play," to use a silly technical term, for really the valve is working when in motion instead of playing.

FIG. 112.



Maudslay's Inverted Circular Valve Connection for Pumps of Marine Engines, as used at the present time.

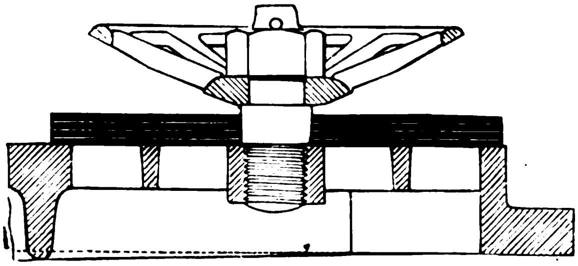
FIG. 113.



Watts' India-rubber Circular Valve, Metal Guard, Stud, and portion of Seating Plate, for Pumps of Marine Engines, as used at the present time.

Messrs. Watt adopted the seating plate similar to Messrs. Penn, but they connected the guard differently, as illustrated by Fig. 113, preferring to use a stud with collars on it, between which the valve was placed, and on the upper collar the guard was fixed by a nut, the stud being screwed into the seating plate.

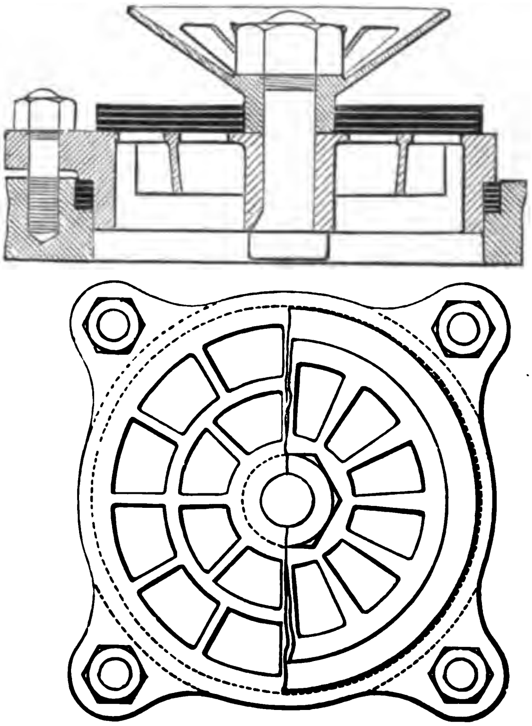
FIG. 114.



Ravenhill's India-rubber Circular Valve, Metal Guard, Seating, and Stud, for the Pumps of Marine Engines, as used at the present time.

The same arrangement was used also by Messrs. Ravenhill, as shown by Fig. 114, but instead of collars the stud was enlarged in diameter between the guard and the seating plate.

FIG. 115.

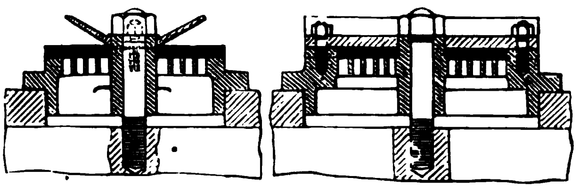


Burgh's Arrangement of India-rubber Circular Valve, Guard, and Separate Seating, for Pumps of Marine Engines, invented in the year 1859.

About twelve years ago we introduced the arrangement which Fig. 115 illustrates, which is far more economical than the previous examples, because it consists of a single valve seating with four, three, or two stud securing projections, according to the size of the valve. A bolt and nut secure the guard and valve, and thus the connection is very simple to manufacture. As this is shown in section and plan, it can be easily understood without further comment.

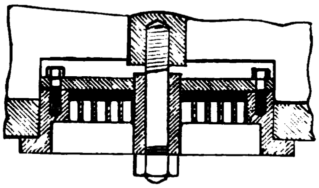
Messrs. Humphrys generally prefer rectangular india-rubber valves fitted with the guards and seatings, as illustrated by Fig. 116 in two sectional views. The seating is secured by one central bolt and nut, and the guard by two studs and nuts: in a similar manner the inverted valves are arranged as shown by Fig. 117, the seating being under the joint flange instead of over it as in the other example.

FIG. 116.



Humphrys' Rectangular India-rubber Valve-Guard and Separate Seating, for Pumps of Marine Engines, as used at the present time.

FIG. 117.

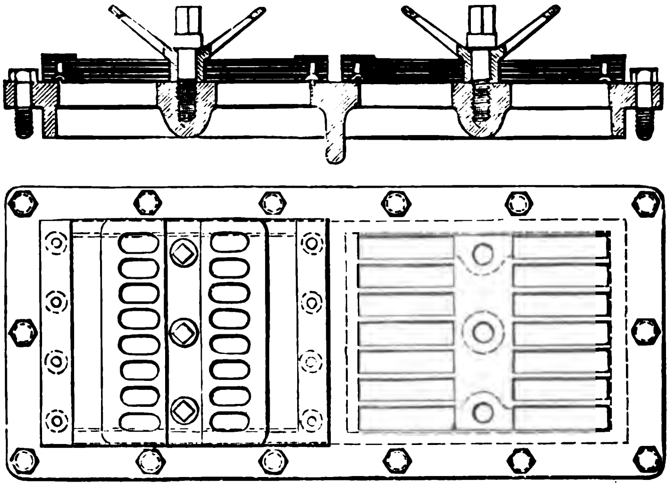


Humphrys' Inverted Rectangular Valve Connection for Pumps of Marine Engines, as used at the present time.

We have often used valves of rectangular shape also, and then secured slips of gun-metal on the valve which prevented its splitting at the outer side edges: the seating was also made in one plate for two valves, as illustrated by Fig. 118, and when for inverted valves, as illustrated by Fig. 119, so that it will be seen, that in both cases the valves and guards are secured precisely alike, and that the same seating, with a very little pattern alteration, suits both positions for the valves.

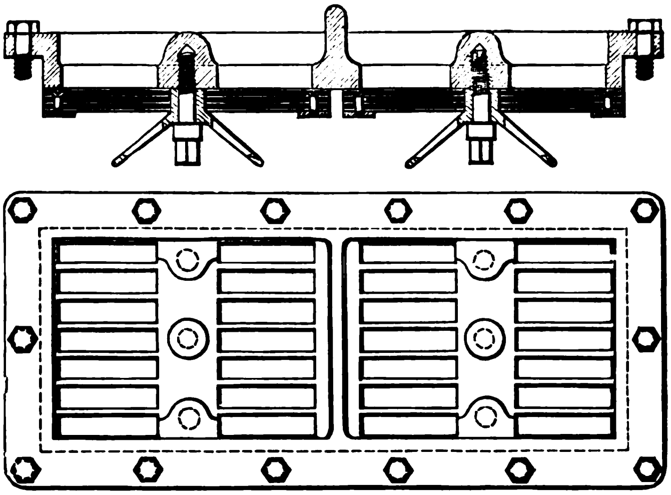
Mr. Spencer has used rectangular metal valves as illustrated by Fig. 120, packed with india-rubber, with the seating peculiarly fitted in a groove which encloses the back and sides of it, while

Fig. 118.



Burgh's Rectangular India-rubber Valves, Seating Plate, and Guards, for Pumps of Marine Engines, as used in the present day.

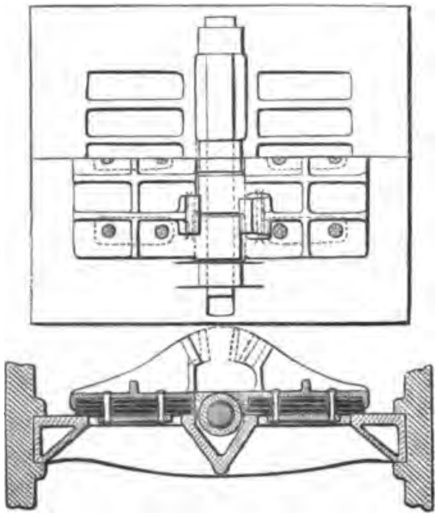
Fig. 119.



Burgh's Rectangular Inverted Valves for Pumps of Marine Engines, as used in the present day.

the door makes the front joint. The guard consists of a projection on each valve, and when they both rise to a certain extent the projections clash, and thus the rise or lift is limited; by which means a similar valve and seating are applicable for the air and circulating pumps, and alterations of the projections on the valves can be made to suit the "lift" as required.

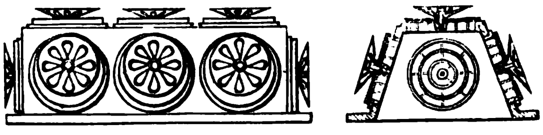
FIG. 120.



Spencer's Twin-flap Metal Valves for Air and Circulating Pumps of Marine Engines, constructed in the year 1865.

We have already alluded to Messrs. Watt's arrangement of valves as shown on page 23, but we think it better to illustrate it again by Fig. 121, as a contrast with the flat seatings just

FIG. 121.

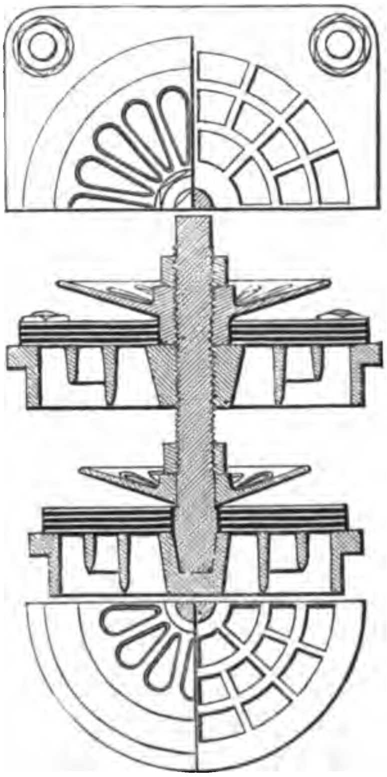


Watt's Box-Seating and Valves for Pumps of Marine Engines, invented in the year 1840.

described, the difference being in the sizes of the seating flange connections for the same number of valves.

Mr. Spencer's method of arranging suction and discharge valves as a combination is shown by Fig. 122, which illustrates that the top seating, for the discharge, is secured by four studs, and the guard stud secures all the remainder of the details, by the simple means that the stud fits into the lower seating as a set cone, and from that point is turned plain to fit the valve and guard, above which it is screwed to the top end, which is square for a short length to fit the securing spanner. The lower guard is plain on the stud and "held" by a nut; the top seating and guard are screwed, so that when the top seating is fixed, the lower one can be secured by the stud—that valve and guard being previously secured by their nut—and then the top guard and valve are made secure.

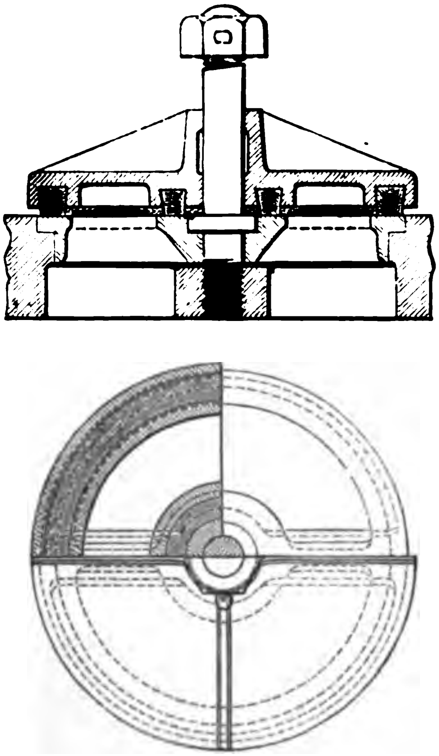
Fig. 122.



Spencer's Arrangement of Suction and Discharge Valves, Seatings, and Guards, for Vertical Pumps of Marine Engines, as used since the year 1864.

The use of canvas and leather as a substitute for india-rubber for valves has of course often been used, but with no success except in their noiseless action; but the same effect can be obtained with all the remaining requirements best by the use of metal valves enclosing wood, lignum-vitæ being the most endurable, and the mode of applying it practically is illustrated by Fig. 123, on the next page, which shows that a disc of metal enclosing a ring of wood acts on a metal seating, which is secured by a stud on which the valve works, and the nut above acts as a stop and spanner head.

FIG. 123.



Burgh's Circular Metal Valves, packed with Lignum-Vitæ, for Pumps of Marine Engines, as used since the year 1866.

CHAPTER XIII.

SUPPLEMENTARY DETAILS FOR THE CONDENSERS OF MARINE ENGINES PRACTICALLY CONSIDERED.

INJECTION VALVES.—These valves admit and stop the flow of the water into the condenser for the condensation of the steam, and the example illustrated by Fig. 124 is the ordinary kind

FIG. 124.

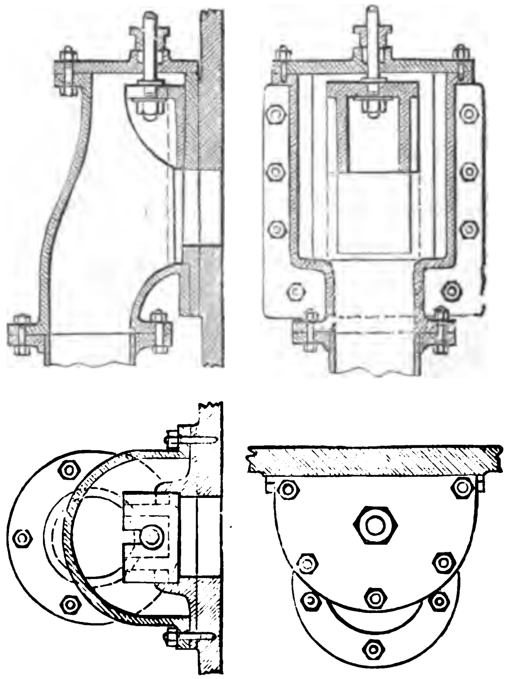
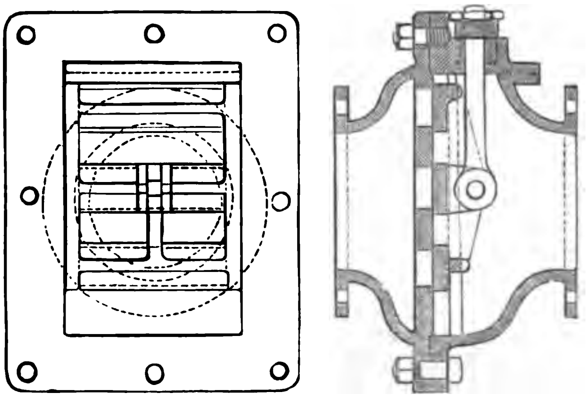


Plate Injection-Valve and Casing for the Condensers of Marine Engines, as used at the present time.

with its casing, seating, and connections; the valve is merely a flat plate working in a groove on each side of the seating, which with the casing is secured to the side of the condenser. The closing of the valve properly is attained by the seating-face being inclined so that the valve tightens as it descends, and "when down" the joint is perfect.

In some instances the valve is hung at its centre with a cross pin and bosses, by which connection the valve is more readily released from being closed than by the former means. An example of this is shown by Fig. 125, where it is seen that the valve is the "gridiron" type fitting on a seating to correspond; and besides the advantage of the connection, there is the reduction of the travel of the valve to open and close the ports, for the admission or not of the water, in much less time than by the former method described; for it is obvious that if the area of the requisite passage is divided into ports or narrow openings, and as the width of one port plus the outside lap of the valve must be the half travel in any case of width of port, then the motion for the valve will be proportionately reduced by the divisions, as illustrated above.

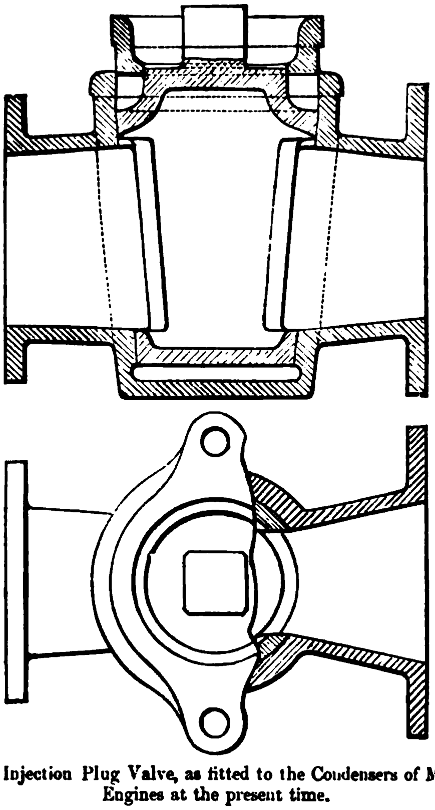
FIG. 125.



Gridiron Injection Valve, Seating, and Casing, for the Condensers of Marine Engines, as used at the present time.

There is another appendage to the condenser of the marine engine that is very important, and although practically so, does not generally receive the merit it deserves. We allude to the "bilge" injection valve, which becomes at times, when the bilge pumps are out of order, the last recourse to "empty the bilges," and that when a leakage or "shipping seas" occurs, must be done in proportion to the supply to keep matters in proper order. We know many cases where this valve has been omitted, and in others where it has been too small, or, in fact, a valve put on because "it is generally done," and for that reason only.

FIG. 126.

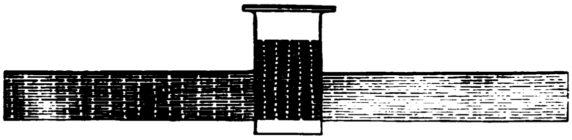


Bilge Injection Plug Valve, as fitted to the Condensers of Marine Engines at the present time.

The universal class of valve for the purpose is illustrated by Fig. 126, which is a common marine "plug-valve," packed at the top and solid at the bottom to prevent leakage if possible. This is not the best valve, however, that can be used, because it is liable to "stick" or become "set," while by using a disc valve, a more clear open communication to the bilge can be better effected at any moment.

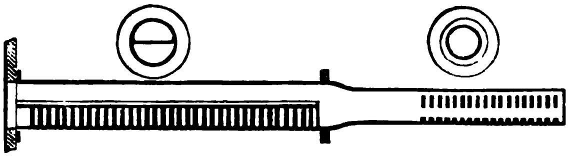
SPRAY-PIPES.—These pipes are for the proper distribution of the water that condenses the steam, and various shapes have been used, as shown on pages 13, 14, 15, 16, 18, 23, 26, 28, 30, 45, and 65, for land and marine engines; but we now direct attention to two popular shapes as used in the present day by two leading marine firms; the illustration, Fig. 127, being by Messrs. Penn, and Fig. 128 by Messrs. Maudslay, which consist in the first case of a perforated pipe with the supply branch at the centre of its length, the perforation being on the upper side only; and in the second case two pipes of unequal diameters, the larger pipe being divided midway, longitudinally by a plate, with the portion below it perforated, and beyond this is the smaller pipe perforated in "streaks" around for its entire length. These two examples accomplish the same requirement; thus Messrs. Penn by the central position for the supply branch, and Messrs. Maudslay by the two diameters for the pipes.

FIG. 127.



Penn's Spray-Pipe, for the distribution of the Injection water in Condensers of Marine Engines, as used since the year 1863.

FIG. 128.

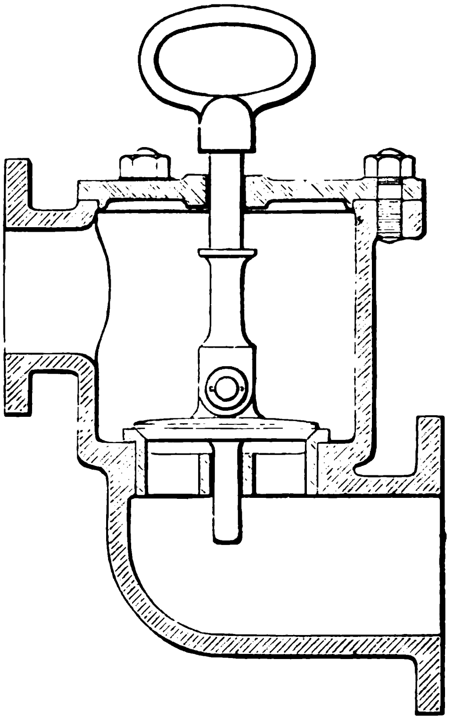


Maudslay's Spray-Pipe, for the distribution of the Injection water in Condensers of Marine Engines, as used since the year 1863.

SNIFTING-VALVES.—These valves are so termed because they are said to "sniff" when in use, that being to allow the condenser to be "blown through" by the steam without a return of air; so that when the steam opens the valve it is said to "sniff," and when the pressure in the condenser is less than the pressure on the valve it closes, and in some instances the valve is loaded either by a weight or spring to ensure that operation.

A very general example is illustrated by Fig. 129, the valve being the disc kind, guided below and fitted with a lifting rod

FIG. 129.

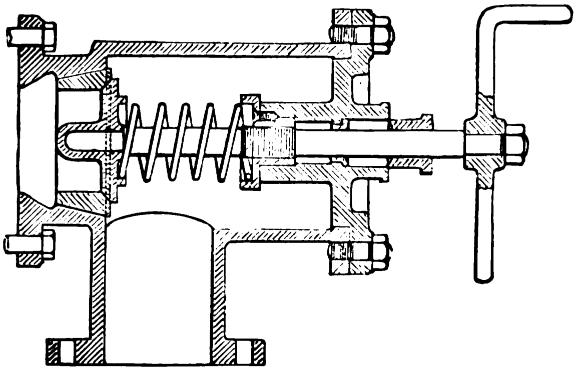


Sniffing Valve and Casing, as used for Condensers of Marine Engines at the present time.

and handle above; the seating is situated sufficiently below the discharge opening to ensure an accumulation of water on the valve while it is closed, and thus prevent any air leakage, the water acting as a weight also.

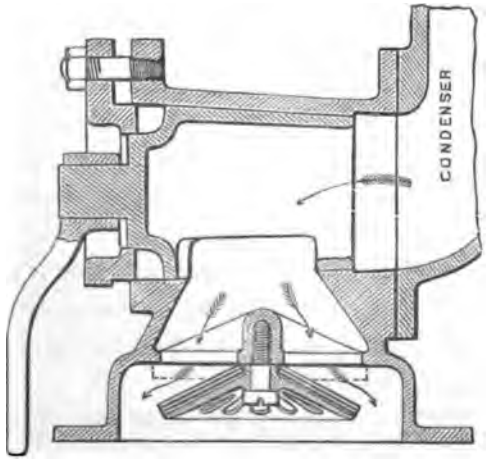
It is very obvious that with this arrangement of casing there will always be water in the branch-pipe under the valve, and to prevent that and ensure a perfect "blow out" of the condenser, we introduced the casing and valve gear as shown by Fig. 130, which is a spring to actuate the valve, and a screw spindle and handle to release and guide it when opened or closed; the spindle also closes the valve independently of the spring, which latter is sufficiently strong only to prevent the valve from sticking on the guide.

FIG. 130.



Burgh's Spring Snifting Valve for Condensers of Marine Engines, introduced in the year 1862.

FIG. 131.



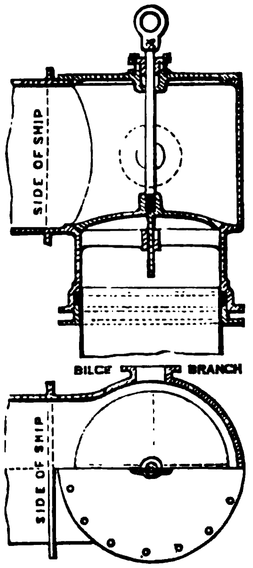
Plug Valve and India-rubber Snifting Valve, for the Condensers of Marine Engines, used since the year 1864.

Plug valves have been used as snifting valves also, as illustrated by Fig 131, which is a sectional elevation of an ordinary plug and casing, fitted with a branch piece, in which is a perforated seating, india-rubber valve, and guard, as used for air pumps. We may add that the closing of the valve depends chiefly on the atmospheric pressure under it.

Water Discharge Valves.—These valves are secured as near the "shell" or "skin" of the hull as practicable, and when open permit the requisite water from the condensers to pass through their casings into the sea or river, and when closed prevent that, and also the influx of the water outside the hull into the air pumps.

Now those two functions may seem so very simple, to many engineers even, that there can be but little to consider as to the best mechanical arrangement for the purposes. It will appear, however,—as we shall directly show—that there are divided opinions now as to the best means. As for example, the illustration, Fig. 132, is a sectional elevation and plan of an ordinary arrangement of valve and casing; the valve being a disc of gun-metal with a spindle-guide and a handle-rod above, to raise and lower it by blocks and tackle attached to a hook secured to the deck or coal-bunker plate. The casing is of gun metal also, with a secured cover above the valve and a stuffing-box branch below it; a bilge-branch is also cast with the casing, to which is attached a smaller but similar casing and valve.

Fig. 132.

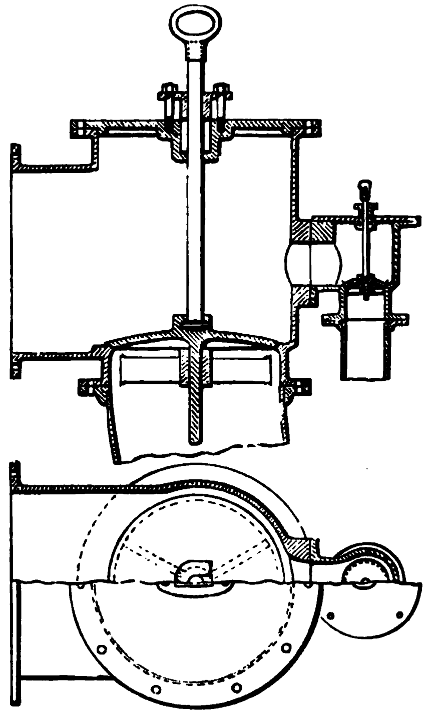


Water Discharge Valve and Casing, for the Condensers of Marine Engines, used since the year 1858.

Instead of the side position for this branch, it is sometimes at the front of the main casing, as illustrated by Fig. 133: the connection of the handle-rod with the valve is different also, because in this case a collar and socket is preferred in the place of a screw and boss.

A third example, as shown by Fig. 134, on page 126, is next worthy of notice, in particular for the gear introduced to raise and lower the valve, which, unlike the previous examples, forms a portion of the arrangement; this is a rack and pinion, with a stop-key to keep the valve opened or closed as required; the spindle is connected to the valve by a cross pin, and the casing has a bilge branch as in the other arrangements. The valve is raised and lowered by turning the pinion-handle, and thus is self-acting, when the stop-key is not in use; the key being more applicable for keeping the valve up than for preventing its rising.

FIG. 133.

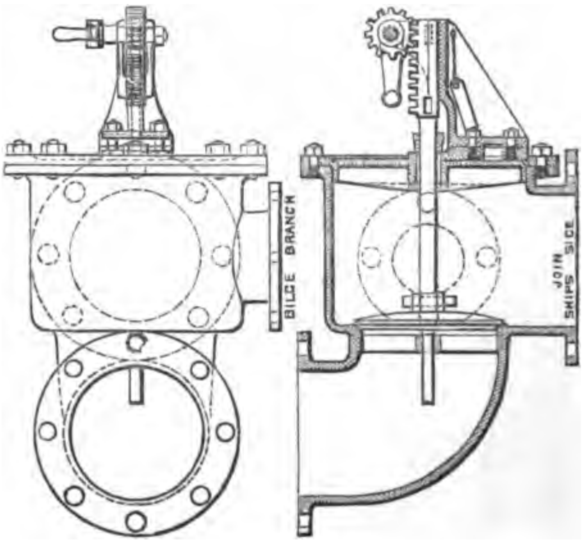


Water Discharge Valves and Casings, for Condensers of Marine Engines and Bilges, used since the year 1861.

The earlier stop-valves of this class had screwed rods and guides to raise and lower them, or as an ordinary steam stop-valve; but after the event of an accident or two, such as bursting the pipe, splitting the pump barrel, and bending the piston rod, they were considered dangerous, and the self-acting valves, as those illustrated, were introduced. Within the last few years the screwed rod has been again adopted, but with a different form of valve, as now illustrated by Fig. 135 : this is the gridiron type of valve and seating, and answers well for large condensers, because the travel of the valve to open and close is so very short proportionately. Those operations can be done in a moment, while the valve also is not liable to "stick" at any point of position.

KINGSTON VALVES.—These valves admit the water or prevent it, from the sea, to the condenser, and as any fracture of the casing or sticking of the valve would render those operations doubtful, a peculiar shape of valve and casing obviating doubt was introduced by a Mr. Kingston about twenty-one years ago, which is used at the present time also, and likely to continue in use.

FIG. 134.

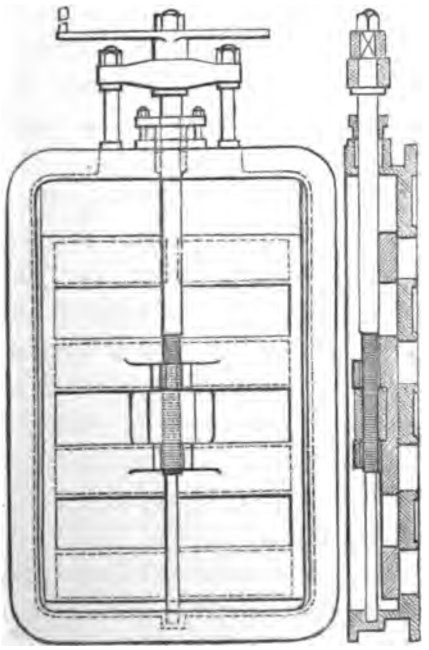


Water Discharge Valve and Casing, fitted with Rack and Pinion Gear, for raising and lowering the Valve, for Condensers of Marine Engines, used since the year 1862.

A section of the valve and casing is shown by Fig. 136; the valve is cone-shaped with the spindle screwed into it, and passing through a stuffing box and gland at the top of the casing surmounted by a cross-handle; the valve is shown closed and locked; the lock being shown in detail at the side of the casing, its application can be readily understood. Below the valve is secured a grating to lugs cast in the casing with guides for the valve; a sectional plan of this portion is shown also.

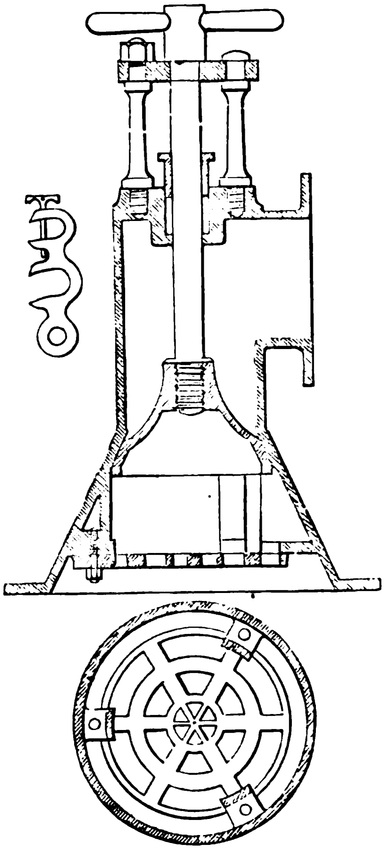
The modern arrangement of these valves and their details is represented by Fig. 137, on the next page, which shows that the

FIG. 135.



Gridiron Discharge Water-Valve and Seating, for Condensers of Marine Engines, used since the year 1864.

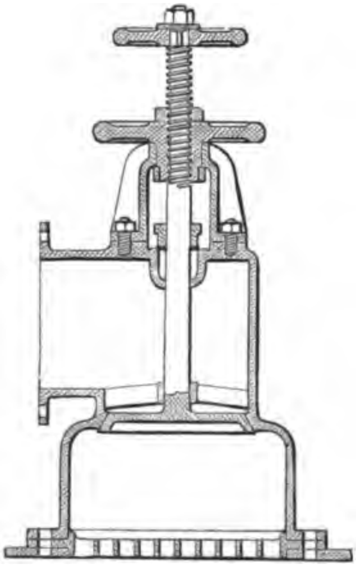
FIG. 136.



Ordinary "Kingston" Valve, for the admission of Injection or Circulation Water to the Condensers of Marine Engines, used since the year 1851.

grating is attached with the casing direct to the ship's side; the valve and spindle are cast together, the top part of the rod being screwed and surmounted with a hand-wheel, below which is a lock-wheel supported in a bracket secured on the casing; this wheel and the smaller one are used to open or close the valve, and the larger wheel locks it, while the nut and the boss locks the spindle and wheel together in any position.

FIG. 137.



Modern "Kingston" Valve, for the admission of Injection and Circulating Water into the Condensers of Marine Engines, used since the year 1866.

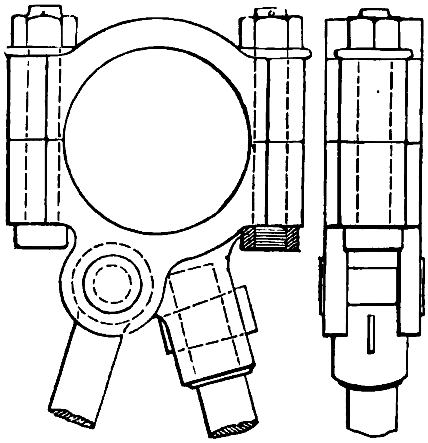
MOTION-GEAR FOR VERTICAL PUMPS.—This gear is chiefly used for the air pumps of oscillating engines, of which several examples are shown in Chapter III.

When two air pumps are used, they are either directly opposite each other in plan, as in Fig. 21, page 23, or the centres are apart equal to the width of the connecting rod bearing, plus the clearance. The arrangement illustrated by Fig. 138 requires only one connection with the crank pin. One rod is keyed into the lower portion of the brass, and the other is hung on a pin on the opposite side. The keyed rod always forms a direct line from the centre of the crank pin, but the opposite rod a broken line at the point of suspension at certain portions of the stroke. The cap is made of wrought iron, and the lower portion of gun metal. The firms most partial to this mode of connection are Messrs. Maudslay, Sons, and Field, and Messrs. James Watt and Co.

Other firms prefer to make the entire portion of wrought iron, with gun-metal lining, to reduce the friction and wear with the crank pin. The trunk end of the connecting rod is secured by a single eye for the rod, and a double eye bolt in the trunk. The bolt is attached to the piston by a nut recessed in the body, by which means a separate provision for clearance is not required in the lower valve plate. The brass in the eye is in the lower half only, as the labour of the pump is greatest when ascending. The adjustment of the pin and brass is often attained by a cotter, on the upper side of the eye; but in many instances this is omitted, as the friction is proportionately slight to that on the crank pin. The rod is in two portions, connected, about centrally of its length, by a socket and key, this being for the purpose of erecting with facility, and portability as spare gear. The dimensions in the table are common with those given on page 23.

The illustration, Fig. 139, on the next page, is the crank end of the connecting rod, belonging to the air pump, shown by Fig. 20 on page 21. In that example the centres of the air pumps are $2\frac{1}{4}$ inches on each side of the centre of the condenser, thus making a difference of $4\frac{1}{2}$ inches for the port and starboard positions.

FIG. 138.



Watt's Twin Connecting Rod Head for working the Pumps of the Condensers of Marine Engines, used since the year 1860.

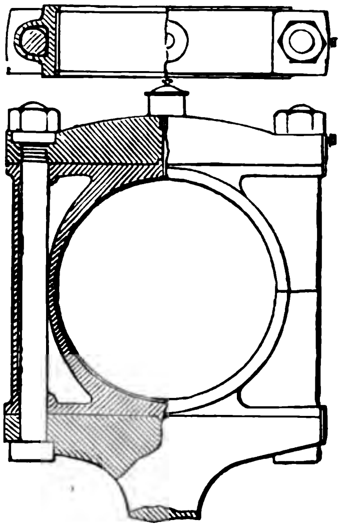
Diameter of Crank Pin, 1 ft. 5 in.

	ft.	in.		ft.	in.
Length of Bearing	0	9	Mean width of Connecting Key .	0	$4\frac{1}{4}$
Diameter of Cap Bolts . . .	0	$3\frac{1}{2}$	Thickness ditto . .	0	$0\frac{7}{8}$
Distance between centres of Bolts	1	9	Diameter of Socket	0	7
Thickness of Cap	0	$2\frac{13}{16}$	Diameter of Lower Socket in Rod .	0	$6\frac{1}{2}$
Diameter of Connecting Pin . .	0	4	Diameter of Trunk Eye Pin . .	0	$3\frac{1}{2}$
Thickness of Eye in Rod . . .	0	$4\frac{1}{4}$	Diameter of Trunk Piston Pin .	0	$4\frac{1}{4}$
Thickness of Eyes in Brass . .	0	$2\frac{1}{4}$	Length of Rod between centres .	12	$5\frac{1}{8}$

The form of the head in the present example is a more general shape than that of Fig. 138. This is to be accounted for from the fact, that independent connection admits of a similar means of disconnection, which, with large engines, is no mean advantage.

The example under notice is shown in sectional and complete views. The cap is of wrought iron, increased in thickness at the centre, to resist the direct line of strain incurred during each stroke of the pump. The brasses are in two portions, the line of division being shown in the complete side of the elevation. Each brass is hollow, to reduce the material, while at the same time the requisite strength is preserved. The T head of the rod is shaped as the cap, and both are connected to the brasses by the bolts, of ordinary description. Each nut is recessed in the cap, and set and stop pins prevent looseness possible.

Fig. 139.



Single Connecting Rod Head for working the Pumps of the Condensers of Marine Engines, used since the year 1858.

	ft.	in.		ft.	in.
Diameter of Crank Pin . . .	1	2½	Thickness of Brasses at top and bottom	0	1
Length of Bearing of Brasses . .	0	4½	Thickness at centre	0	0½
Diameter of Cap Bolts . . .	0	2	Diameter of Connecting Rod at T head	0	4¼
Distance between Centres of ditto	1	5½	Diameter of Eye Pin . . .	0	3¼
Width of Cap and T head . .	0	4¼	Diameter of Trunk Pin . . .	0	4¼
Thickness of Cap at Centre . .	0	3	Length of Rod between Centres	9	8⅜
Ditto ditto Ends . .	0	2			
Thickness of T head	0	1¾			

The dimensions under this illustration are connected with those given on page 21.

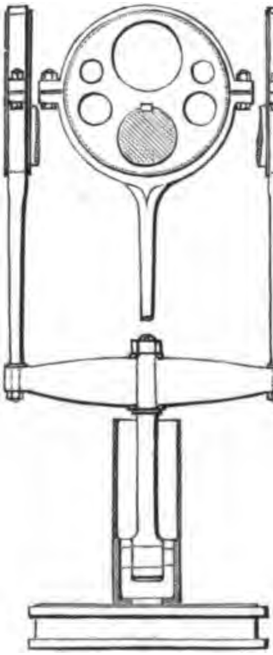
In some instances it is preferred to make the head of two solid portions, with thin circular or octagon brasses. An example of this kind has been designed by the author for the air pump of a pair of engines of 150 nominal horse power collectively, alluded to by Fig. 23 on page 26. The diameter of the crank pin is $9\frac{1}{2}$ inches, the cap bolt $2\frac{1}{8}$ inches, and the length of connecting rod, between centres, 5 feet 6 inches. Each nut is recessed in the upper portion of the head, and set screws $\frac{1}{2}$ inch diameter prevent looseness. The brasses are $\frac{3}{4}$ inch thick at the line of strain, and $\frac{3}{8}$ at the sides; the flanges being $\frac{3}{4}$ inch in thickness, and length of bearing 6 inches. The cap or top portion is $2\frac{1}{2}$ inches thick, and that formed with the rod the same, at the angles with the brass.

The next means of imparting motion to the air pump piston is by eccentrics, which are now general. The firm most partial to this mode of action is Messrs. James Watt and Co., who have lately fitted no less than five vessels with diagonal oscillating engines and eccentric motion for the air pumps. Messrs. Ravenhill and Laird also have constructed engines of similar type, and other firms in England and Scotland often adopt the same arrangements. In fact, so universal is the system, even for engines of moderate power, that the new saloon steamers on the Thames are fitted accordingly.

The motion under notice has the advantage that one or two eccentrics can be arranged to work the same pump. Now, with two eccentrics, the strain on the intermediate shaft is transmitted close to the bearings, a matter of great consideration with large engines, when the distance between the centres of the entablatures is considerable. One fact, of course, in connection with the duplicate motion, is that a crosshead is requisite, or additional detail, but the shaft can be of less diameter than when the crank or single motion is adopted. Other facts also are apparent, such as the reduction of the labour and material for the shaft; and when the piston rods of the cylinders are connected on the same crank pin, the single or twin eccentric motion is adapted to work the air pumps in the wings of the engine room.

The illustration, Fig. 140, is an example of twin eccentric motion. The trunk and piston are of the ordinary kind, also the connection of the rod. The eccentrics are shown in end and side elevation, to render their form obvious.

Fig. 140.



Twin Eccentrics, Rods, and Piston, for the Pumps of Condensers of Marine Engines, used since the year 1864.

	ft.	in.		ft.	in.
Diameter of Trunk . . .	0	11	Diameter of Eccentric Bolts .	0	1¼
Length of ditto	2	6¾	Width of Eccentric . . .	0	4¼
Distance between Centres of Pin and Crosshead . . .	2	5⅜	Width of Eccentric Band . .	0	3⅛
Distance between Centres of Crosshead and Intermediate Shaft	4	0¼	Distance between Centres of Eccentrics	3	7¼
Diameter of Intermediate Shaft	0	10	Depth of Crosshead at Centre .	0	9¼
Diameter of Crosshead Rod .	0	3½	Ditto at Ends . .	0	4
Diameter of Eccentric Rods .	0	2¾	Diameter of Boss at Centre .	0	6½
Diameter of Eccentric . .	2	2¾	Ditto ditto at Ends . .	0	4½
			Thickness of Web at Boss . .	0	2½
			Ditto ditto at Eye . .	0	1¼

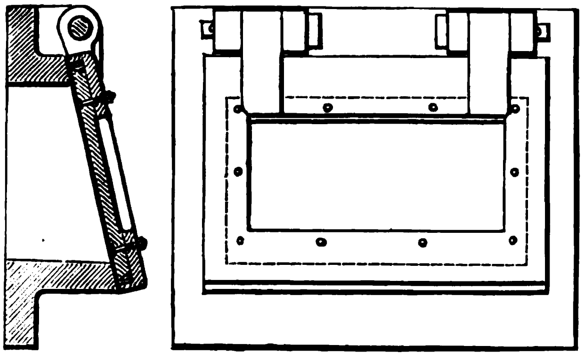
For an air pump 3 feet in diameter, and a stroke of 15 inches, the dimensions under the illustration are in practice by Messrs. Ravenhill, fitted in a merchant ship.

CHAPTER XIV.

ARRANGEMENTS OF PUMP-VALVES FOR LAND ENGINES PRACTICALLY CONSIDERED.

It will be remembered that on page 117 we illustrated a guide rod metal valve packed with wood, of a circular form, as applied for pumps of marine engines; and now, by Fig. 141, we illustrate another method for a hinged rectangular shape that has been applied with land engines. The main feature in this case is, that the frame of the valve is recessed to receive an angular edged plate of lesser dimensions in length and width, and the space between them is filled with wood, cut across the grain to fit therein, the frame and plate being connected by bolts and nuts. This being shown in section and complete elevation, it can be easily understood, and thus enables us to

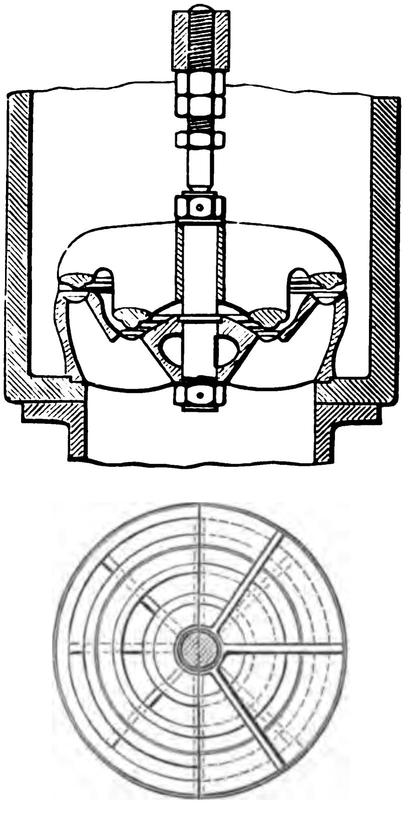
FIG. 141.



Rectangular Wood-Packed Metal-hinged Valve and Seating, for the Air Pumps of Land Engines, proposed in the year 1858, by H. C. Bosscha, a Dutch engineer.

refer to the next example, shown by Fig. 142, which is a double stop surface circular metal valve and seating: the reason for there being two stop surfaces is, to reduce the shock or blow of the valve when closing the apertures for the discharge of the water through the seating. The valve is guided on a bolt secured in the seating by a nut, and the seating is fixed by a set stud acting on the top end of the bolt, and is screwed through a cross-piece cast with the valve-chamber.

Fig. 142.

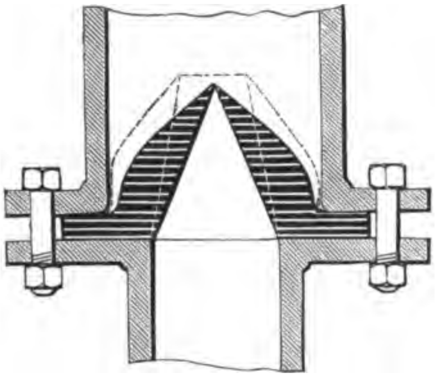


Double-Seat Metal Valve, for the Pumps of Land Engines, applied in the year 1854.

Our next illustration is of a far more simple character, as shown by Fig. 143, which represents a flanged tube of india-rubber flattened at the top, thus forming "lips," that open to permit the discharge of the water and close to prevent it, their position when open being shown by dotted lines.

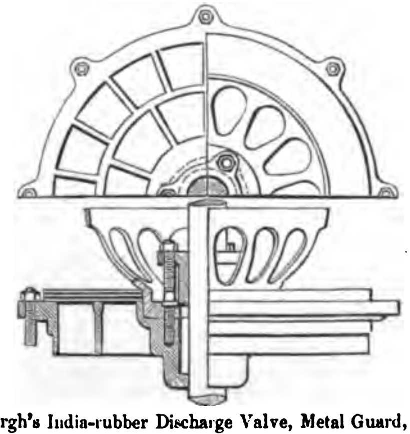
Referring next to valves and seatings of more general use, the example shown by Fig. 144 is noticed, which is a section and half plan of our usual method of design and connection for valves, guards, and seatings for air pumps of beam engines. The stuffing box and gland shown in the centre is for the piston rod to work through when used as a discharge valve, but when applied for suction the guard is secured by a single stud centrally fixed.

FIG. 143.



Perreaux's Vulcanised India-rubber Valve and Seating, in *one* piece, invented and patented in the year 1857.

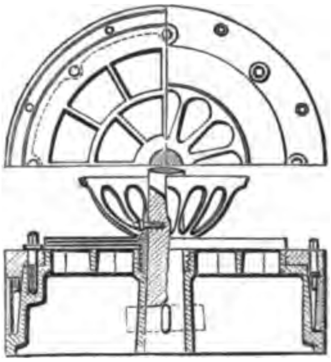
FIG. 144.



Burgh's India-rubber Discharge Valve, Metal Guard, and Seating, for Air Pumps of Land Engines, as used since the year 1862.

For pistons of air pumps which have the seating formed in them, and the valve and guard attached, the arrangement shown by Fig. 145 is a good example: we arranged this in the year 1863, and one of the features worthy of comment is the packing, which is a metallic ring, that is adjusted by a gasket or india-rubber behind it, actuated by a ring and set studs. The securing of the guard was novel then also, being by studs to the piston rod. We may add in passing that this and the preceding figure are in conjunction with Fig. 11 on page 14.

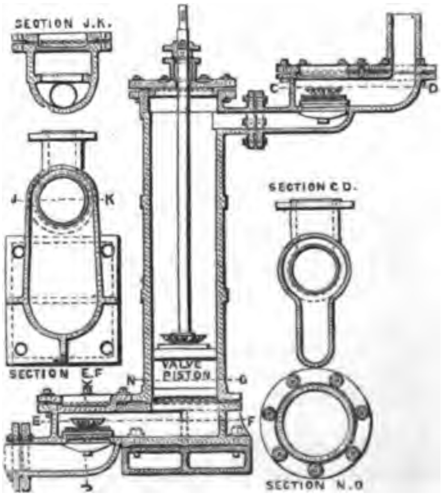
Fig. 145.



Burgh's Piston, Seating, Valve, and Guard, for Air Pumps of Land Engines, as used since the year 1863.

It sometimes occurs that the correct positions for the valves must be sacrificed to immediate, and, therefore, separate accessibility; which when occurring, the arrangement shown by Fig. 146 has been used by a well known firm. The suction and

Fig. 146.

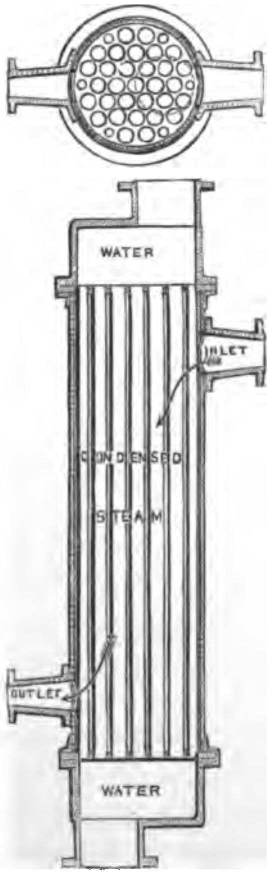


Arrangement of Air Pump and Valves for the Surface Condenser of a Beam Engine, constructed by Messrs. Whieldon, Lecky, and Lucas, for the Luton Water-Works, in the year 1869.

discharge valves are at the sides of the barrel, and the piston has a valve on it arranged very like Fig. 145, the other valves being similar as introduced by Messrs. Maudslay and illustrated on page 110.

The condenser in connection with this pump is illustrated in sectional elevation and plan by Fig. 147: it is a plain cylinder fitted with tubes and branches; the steam enters the shell inlet, and passes as condensed water through the outlet below, while the water passes up through the tubes.

FIG. 147.



The Surface Condenser in Connection with the Pump shown by Fig. 146.

CHAPTER XV.

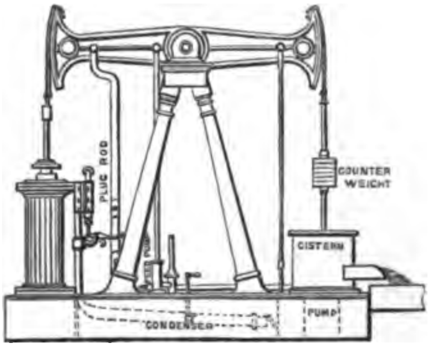
THE APPARATUS FOR THE CONDENSATION OF STEAM WITHOUT AIR PUMPS.

WATERFALL CONDENSERS.—About twenty-seven times as much water as feed is required to keep down the temperature of the ordinary condenser to 100 deg. or thereabouts, and thus maintain a vacuum short of the atmospheric pressure by 2½ lbs. to 3 lbs. per square inch. Half a cubic foot of water evaporated per hour will in a moderately good engine give one indicated horse-power, and as 1 lb. of coals in a fair boiler will evaporate 7 lbs. of water, this corresponds to a consumption of fuel per horse-power per hour of 4·571 lbs. Properly to condense the waste steam from such an engine, 13·5 cubic feet of water will be required per hour for each indicated horse power. Under certain circumstances it would be possible to construct a reservoir, tank, or condenser strong enough to resist an atmospheric pressure of 11 lbs. or 12 lbs. per square inch, and large enough to contain the products of condensation for half an hour. Thus in the case of an engine working up to 100 horse power, some 1350 cubic feet of water would be required per hour, or 675 ft. in half an hour, which would be contained and something to spare in a cylinder 9 ft. 6 in. in diameter and 10 ft. high. If such a vessel were applied to an engine in lieu of an ordinary condenser, the steam might be condensed within it, and if no air entered a perfectly good vacuum might be maintained without any air pump whatever. When the vessel was nearly filled the injection might be shut off, a large valve opened at the bottom, and the entire contents blown out by the pressure of the exhaust steam and the gravity of the water. This operation, under proper arrangements, would not occupy more than a minute. On closing the lower valve and readmitting the injection the vacuum would be restored, and the engine would proceed as before, and the operation of blowing out might be effected automatically by a simple float arrangement. Unfortunately such a plan would not work well in practice, because of the air which would accumulate in the condensing chamber and spoil the vacuum. We mention the arrangement here only because it illustrates a principle.

If now, instead of suffering the condenser to work for half an hour at a time without blowing through, we suppose its contents—in so far as they consist of air and water—to be expelled at much shorter intervals, say of half a minute, the entrance of air would be productive of little inconvenience. But then during a few seconds in each half minute the engine must work without the aid of a vacuum. Thus we can suppose the engine to work for twenty strokes with, and for five strokes without, a vacuum; and such an arrangement would undoubtedly be admissible in practice, and might be used to advantage under peculiar circumstances. But there are far better arrangements by which a similar end may be attained. By employing an air pump the action of the condenser is rendered nearly continuous instead of intermittent; but there is no power gained thereby. It may be demonstrated that the power expended in working the air pump continuously is greater than that which would be wasted during the interval occupied in blowing out the condensing tank we have described.

Carrying our illustration a step further, we may suppose that the condensing tank is blown out at each stroke. With each reduction in the length of the intervals elapsing between each operation of this kind, it is obvious that the dimensions of the tank may be reduced. Thus if the tank be blown out every ten minutes, it may be reduced to one-third the size required when blowing out takes place every half-hour; and if the operation be effected at each stroke of the engine, a very small space indeed will answer, as is seen when the air pump is employed, the action of which is, in effect, to blow out the condenser once at each double stroke of the steam piston. If the blowing out be effected by shutting off the injection at each stroke, and permitting the steam to expel the contents of the condenser, then it may be urged that no vacuum can be obtained, but this is an error. The action will then be divided into two portions. The waste steam first expels the contents of the condenser, and is then itself condensed, leaving a vacuum. As a result, the first portion of each stroke will be performed without, and the latter portion with, the aid of a vacuum; and it may be shown, that although the action is thus far intermittent, no more power is wasted than by the air pump.

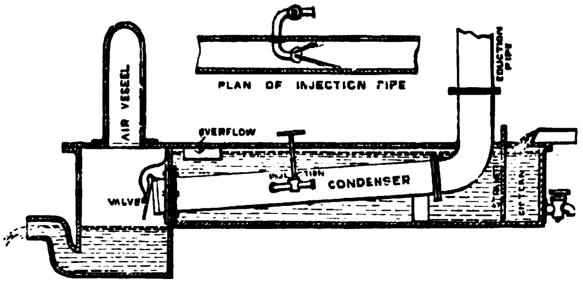
FIG. 148.



Dr. Alban's Single-Action Engine and Air Pump, invented by him in the year 1826.

Such an intermittent condenser as we have last mentioned has actually been used in practice, and with very good results. It was first, so far as we are aware, proposed and used by Dr. Ernest Alban, of Plau in Mecklenburgh, as far back as 1826, as illustrated by Fig. 148, which shows a little pumping engine to which it was fitted. Dr. Alban thus describes the engine:—"The engravings represent an engine erected by me for lifting water at Dobberan Turf Moor. In this I have used a pump beam, though it is by no means absolutely necessary. The engine cylinder is constructed for single action, *i.e.*, working by the descent of the piston only. The valve is a slide, and the beam has on the ends two arcs, to which the piston and pump-rods are hung by strong straps which, as the engine is small, answer very well; the framing and the pump, which is of copper, furnished with a cistern and run-off trough; the pump-rod, the counter-weight, the condenser, and the feed-pump, are all shown, as also is a catch-rod, to prevent the engine making too long a stroke either way. The lower end of the cylinder is always open to the condenser, by the side pipe. The steam is cut off at half stroke. At the end of the stroke the steam blows into the condenser, and a vacuum is quickly formed above as well as below the piston. The counter weight then acts, and the piston goes out, at the end of which the valve is reversed by the plug-rod, and the return stroke repeated as before.

Fig. 149.



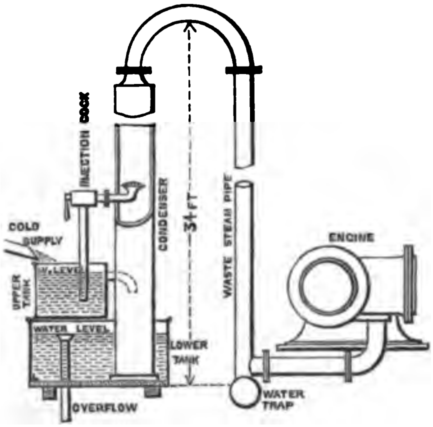
Dr. Albau's Condenser, Tank, and Pipes, invented in the year 1826.

The illustration, Fig. 149, shows the eduction pipe, the condenser, a pipe of sheet copper, the same diameter as the eduction pipe, and about twice the length of the stroke of the engine. It lies in a cistern supplied with water from a pipe, a strainer is fixed to prevent any particles of dirt getting into the part of the cistern from which the water is drawn, and there is an overflow by which the waste runs off, also there is an emptying cock. The condenser is laid on an incline; the lower end projects out of the cistern into a box, and is furnished with a hanging flap-valve opening outwards; a small pipe is fitted, in which is fixed the injection cock, turned by the key. The pipe is bent in the interior of the condenser, and has a mouthpiece so shaped as to spread the jet of water. The action of this condenser is as follows:—At the moment the eduction passage is opened to the cylinder, the steam having a pressure considerably above that of the atmosphere, rushes through the pipes, stops the injection, and blows the water and air collected in the condenser out at the valve into the vessel. This, however, is the work of a moment; the valve immediately falls, the jet of water again enters, and the steam is condensed. The air and vapour pass away by the pipe—and the water by the pipe. It is to be regretted that Dr. Alban did not measure the vacuum obtained by this condenser. But he proves the efficiency of the apparatus by stating that either of the engines to which it was applied could be stopped when working with full steam by simply closing the injection cock.

We have in this arrangement a true intermittent condenser, and our readers will not be slow to perceive that the waste steam takes the place of the air pump piston very efficiently. At the commencement of each stroke the steam exhausts into a vacuum, which is quickly destroyed and then restored again. Power is of course wasted, because a portion of each stroke is performed against atmospheric pressure. But it must not be forgotten that the ordinary air pump works also against atmospheric pressure, and consequently consumes power; and it might be possible so to construct an Alban condenser that even in practice its results would not be greatly inferior to the ordinary condenser. It is obvious that the great end to be sought is the rapid condensation of the steam and the restoration of the vacuum. But in the Alban condenser the flow of injection water cannot be re-established until the pressure within the condenser falls to something below that of the external atmosphere, and this can only be attained by the condensation of the steam within the waste-pipe or condenser by the abstraction of heat through the metal. To make the apparatus more perfect, the condensing water should enter under such a head that only at the first instant of exhaust would the injection be stopped; and by this means the no-vacuum period might be so far reduced that the Alban condenser would be made highly efficient.

We now refer to a condenser differing in many respects from any we have yet alluded to, and apparently capable of giving a first-class vacuum with as much steadiness as though an air pump were used. In all the condensers we have mentioned both air and water are required to be expelled by the exhaust steam. In that the principle of which we are now going to describe only the air is so expelled; and if no air found its way in, either with the injection or from the boiler or engine, it would be perfectly continuous in its action.

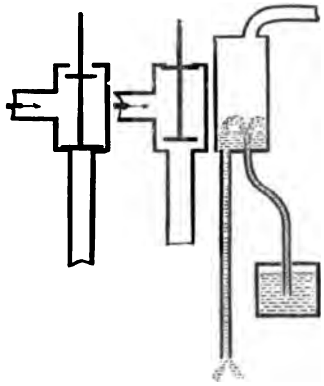
Fig. 150.



Arrangement of Waterfall Condenser without an Air Pump, proposed in the year 1868.

In the illustration, Fig. 150, there is shown the waste steam-pipe from an engine prolonged to a height of 34 ft., turned vertically downwards, and immersed at its lower end in a tank containing water. It is evident that by merely throwing a jet of water into the pipe we might have a most efficient condenser. The water would perhaps stand at some 28 ft. high in the pipe above the level of the liquid in the tank, and as the injection and waste steam water accumulated, it would tend to increase the height of the column, which, not being balanced beyond a certain point, would gradually sink down, and so the products of condensation, as we may call them, would gradually pass away into the lower tank. For each inch added at the top of the column in the stand-pipe, an inch would escape at the bottom. The column would, in short, act the part of an admirable pump in all respects but one. It would not withdraw the air, which would gradually accumulate until the pipe filled and the vacuum ceased to have any existence. Then the waste would blow through and expel the air. Under certain conditions the steam would next be condensed, and the vacuum be restored; but for much of its time the engine would work against back pressure. By the aid of a small pump, however, the air alone may be withdrawn, and with this addition the gravity condenser becomes very efficient.

Fig. 151.



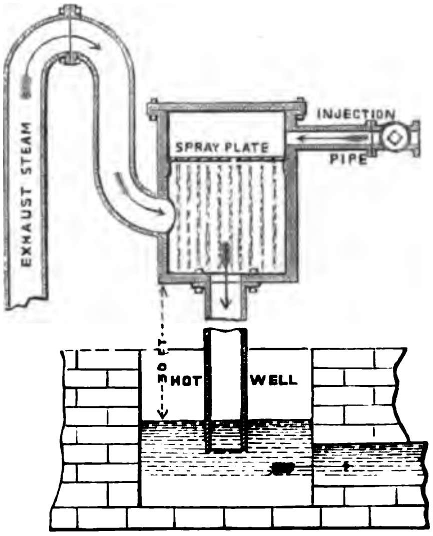
Diagrams of Valves, Boxes, and Waterfall Condenser, proposed in the year 1868.

But a fall of 34 ft. is essential to such a condenser, as with a less fall, water might regurgitate into the cylinder, and this fall can be had in very few cases. It is not easy to provide a tank 34 ft. below an engine and a good discharge for the waste water at the same time. To pump the waste up would be poor economy, so this form of condenser is seldom or never used. If, however, instead of placing the tank below the level of the engine, we put it on the same floor, and carry the steam up to a height of 34 ft. above the tank, we shall attain the same end.

A diagram of the well-known syphon fountain is shown on the right hand of Fig. 151. From the bottom of a cylindrical glass vessel proceed two tubular legs, one much longer than the other, the shorter ends within the glass in an adjutage or jet. On immersing the shorter leg in a vessel of water, and partially exhausting the air from the apparatus, the water will spout up into the glass as shown, and flow away by the longer leg, in which a column of water will stand determined in height by the degree of exhaustion within the glass. If, now, steam were admitted through the top of the glass at the top pipe, it would be condensed continuously by the jet; and if the long leg were 34 ft. long, and the orifice of the short leg so contracted that water could not get in fast enough to partially fill the upper vessel or condenser, and so spoil the jet, we should have a perfect condenser. And it is obvious that the situation of this condenser in relation to the engine, would be of little moment, as the waste steam pipe might be led in any direction and to any height.

We have yet to explain how the air is to be got rid of and the water, which results from the condensation which must take place in the rising steam pipe, to be expelled from the apparatus. The top of the syphon, however, would really terminate in a box fitted with two valves, so arranged that before one was opened the other must be closed, as roughly illustrated in Fig. 151. In the rising pipe little or no air will accumulate, as the constant current of steam will carry it forward into the top of the descending main. The space allowed above the standing column of water should not be too great. In the absence of the box the air could only be expelled by shutting off the injection and suffering steam to accumulate till the water was driven out of the down pipe, and the condenser well blown through. Unless the injection tank stood high the injection would not flow again until condensation took place and a partial vacuum was restored; but to do this the engine must be stopped or the waste steam turned out of the apparatus, and even then it would be a work of some little time. By the use of the expedient shown this objection—an objection great enough to condemn the whole principle—is got rid of. When air accumulates the valves are to be drawn down. The injection will still flow, and the column of water in the stand-pipe remain unaffected in height, because the lower valve effectually prevents the entrance of air. The waste steam will then escape through the upper orifice instead of being condensed, carrying with it much of the air. After a couple of strokes of the engine the valve is restored to its normal position, as in the central figure, and condensation proceeds as before, without a moment's loss of time. All the air cannot be thus removed, but a little reflection will show that its quantity can thus be kept within limits incapable of materially affecting the vacuum. The action of the valves can be rendered automatic by many devices which will suggest themselves to our readers; and we need hardly point out that the arrangement of this air-trap, as we may term it, admits of great modification.

Fig. 152.



Shirt's Waterfall Tank Condenser and Pipes, patented in the year 1862, but used in sugar refineries ten years previously.

The water of condensation may be collected in a ball or trap, and thence expelled at the moment the air-trap is in action, or it may be got rid of by a modification of the ordinary steam-trap.*

A very simple arrangement of waterfall condenser and piping is illustrated by Fig. 152, that has been used in sugar refineries during the last twenty years, but has been patented by a Messrs. Shirt and Briggs, of Tamworth, for the condensation of the steam of high pressure steam engines, for which an air-tight tank is connected to the exhaust pipe of the engine; and above the point where the exhaust pipe is jointed to the tank, there is a perforated partition for dividing the condensing water into numerous streams. The condensing water is introduced by a pipe at the upper part of the tank, from a cistern or otherwise, so as to keep up a constant supply, which may be regulated by a cock or valve. From the lower part of the tank a waste water pipe descends, and the lower end of such pipe is constantly covered with water in a well or cistern. The exhaust steam flows from the steam cylinder into the tank, and is there condensed, whilst the fresh steam in the cylinder acts on the piston, which on the other side is subject to a partial vacuum.

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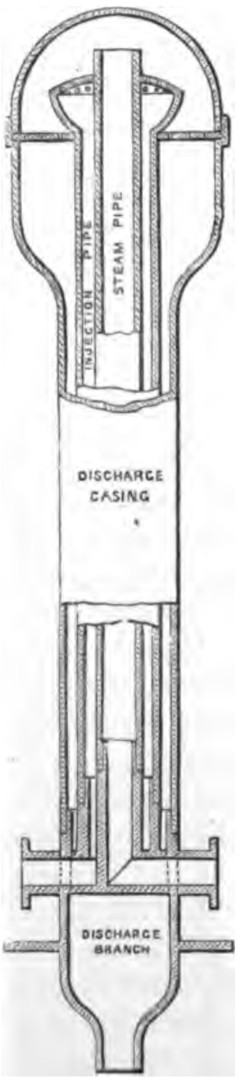
* See "Engineer," Oct. 2nd, 1868.

FIG. 153.



Parry's Annular Tubular Condenser, worked by a Waterfall, and no Air Pump, patented in the year 1865.

A more complicated arrangement is illustrated by Fig. 153, which is "fed" by water that rises into the apparatus at a pressure either due to the height it falls from or by the vacuum caused. The mechanical construction is thus:—

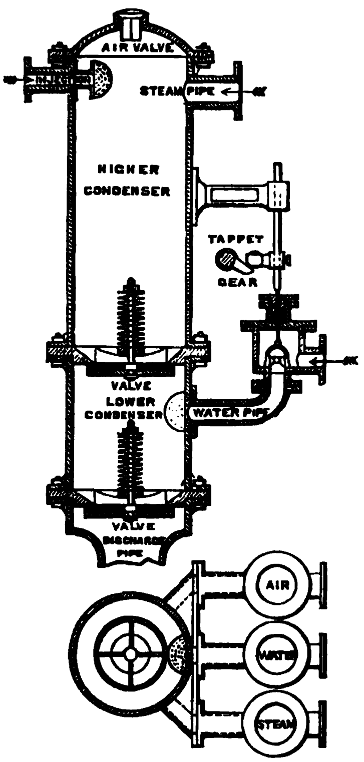
The injection pipe surrounds the steam pipe, so that the injection water will partially condense the steam in that pipe before it reaches the top part of the condenser. The discharge pipe or passage is the annular space formed by the outer case which surrounds the injection pipe. The discharge pipe descends beyond the cross branch pipes, and passes through the discharge branch into the hot well. The three pipes are arranged concentrically one within the other, and are thus combined in one pipe, and are connected with the shell of the condenser. In this manner the unequal expansion of the pipes is accommodated, and support is given by each to the other. The top end of the steam pipe is open, and discharges the escape steam against the cap or cover of the condensing chamber. The rose upon the upper end of the injection pipe fits loosely around the steam pipe, and the perforated plate is also fitted loosely around the injection pipe, in order to compensate for any unequal expansion or contraction of the pipes. This apparatus must stand in such a position as will give the discharge pipe a perpendicular fall of water to the hot well of thirty-four feet, or a column sufficient to balance the weight of the atmosphere.

The operation of the condenser is as follows:—The steam branch pipe being connected with the exhaust pipe of the steam engine, and the injection pipe being made to communicate with the rose, which is connected to a suitable injection pump if preferred, the engine is started, the exhaust steam and injection water through the rose come in direct contact, and the velocity of both being stopped by the cap, or top of the condenser, time is given for a thorough mixture of the cold water and steam. Condensation will then take place, and the water, by falling upon the perforated plate, will be further detained in order to give time for a perfect condensation of the steam; the condensed steam and water will then fall down into the discharge pipe through the plate. The discharge pipe being open at the lower end and submerged below the surface of the water in the hot well thirty-four feet from the condenser, a column of water is obtained whose weight equals that of the atmosphere, and will therefore exhaust the condenser, and draw all the condensed water from the engine and escape pipe over into the discharge pipe, and also lift the water of injection in the pipe from a depth proportionate to the vacuum formed in the condenser.

A still more curious apparatus has been invented and applied with success by Mr. M'Carter, of Londonderry, as illustrated by Fig. 154, in sectional elevation and plan.

The working of this apparatus is that the condensation is effected by injecting cold water into the condenser, which is made in two compartments, higher and lower. The exhaust steam pipe from the engine communicates with the top of the higher compartment, and this has in the bottom an aperture, with a valve opening into the lower compartment, whilst the latter has also in its bottom an aperture, provided with a valve opening into the discharge pipe. The injection water enters by a nose nozzle projecting into the upper part of the higher compartment. A valve is on the top of this condenser, for allowing any escape of air when blowing through before starting...

Fig. 154.



Carter's Double Condensers and Tappet Valve Gear, for the condensation of steam without an Air Pump, applied in the year 1869.

The condenser valves which open the communication between the higher and lower condensers, are metal discs, faced with india-rubber, and are kept in their places by spiral springs coiled round each spindle, the requisite amount of elasticity being regulated by a screw and nut above. Previous to starting the engine it is necessary to blow the air out of the upper vessel. This is done by a small pipe and cock from the boiler. Tappet gear and air, water, and steam valves are in connection with the lower condenser.

The engine being started, the condensation goes on in the ordinary way, the injection water being brought from the river or tank by the vacuum formed in the condenser. The engine having made a certain number of strokes, steam from the boiler is admitted through the steam valve, which displaces any air which may be in the lower vessel. The water valve being then opened, a small jet of water is thrown into it, which condenses the steam used for displacing the air, thereby forming a vacuum, similarly as in the upper vessel, upon which the upper condenser valve opens and allows the products of condensation to fall into the lower condenser. By the revolution of the shaft and tappets the air valve is then opened, which destroys the vacuum in the lower vessel, and allows the water to fall down the waste pipe, the operation being repeated continuously.

The steam pipe from the boiler to the lower condenser, used for displacing the air and forming the vacuum, is furnished with a reducing valve, by which the pressure is reduced to about one pound above the atmosphere, this being found sufficient pressure for the purpose, and making the quantity of steam used very small, because the lower vessel only requires blowing out at about every fifteen to twenty strokes of the engine; that being, of course, operated by the tappet gear.

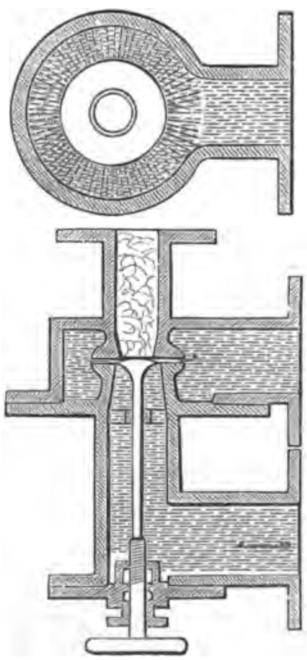
EJECTOR CONDENSERS.—The introduction, about fifteen years ago, of Giffard's injector for feeding boilers, created a great deal of wonder amongst the unthinking engineers who could not comprehend how a boiler could "feed itself," as we heard it expressed then, without a water pressure under the feed valve as in Watt's time. It seemed puzzling why steam and water combined should overcome the same initial pressure of steam in the boiler, and therefore enter the same as feed water. The secret, however, was contained in the fact that the injector was a *condenser*, and thus atmospheric pressure was added to that of the steam, and the two pressures combined being more than the steam pressure, the water was easily forced into the boiler.

A whirlwind of ideas soon came into contact, and sundry inventors rushed to protect their improvements, as they termed them, on the original injector—which by the way is the best after all—and about ten years ago a bright conclusion came to light from some one, that the injector was actually an *ejector*; thus the whole of the tirade of former explanations were rattled away as so much lost work and base thought.

We have attended meetings at some of our leading institutions, and heard the injector explained in volumes of language, illustrated with innumerable diagrams, but with no conclusion beyond it being a wonder; whereas, in point of fact, if the matter had been considered naturally, and therefore simply, it would have been understood there and then, that it was the *condensation of the steam* that caused the result, and nothing more. We did hazard once in our mild way that such was the case, by way of explanation, but our efforts were so speedily crushed by the learned in the case, that we gave up the contest.

In the year 1863 Messrs. Barclay and Morton, of N. B., patented an ejector condenser, as illustrated by Fig. 155. The actuating pressure enters by the vertical top branch, and the fluid acted upon enters by the lowest branch; then both fluids unite between the two flat annular fixed surfaces within the intermediate or discharge chamber. The adjustable conical centre piece is formed with its spindle, which passes through a stuffing-box, and on it is fixed a hand wheel, which serves to regulate the admission of the fluids by a screw chased upon the spindle itself, and working freely within a corresponding thread formed in one end of the apparatus. Near to the conical centre piece a guide is formed with three or more radiating arms extending to the interior sides of the apparatus, so as not to obstruct the passage of the fluid.

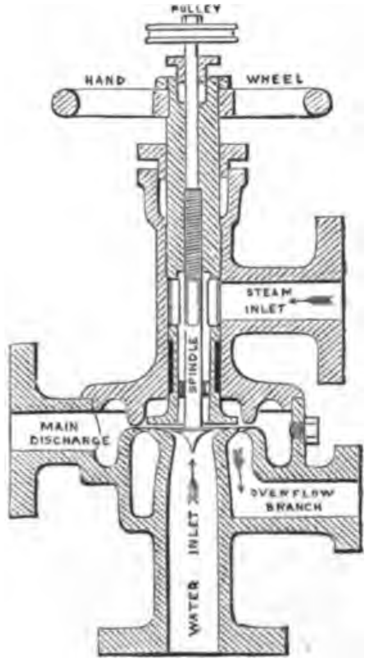
FIG. 155.



Barclay's Disc Ejector, as applied for the discharge of fluids, patented in the year 1863.

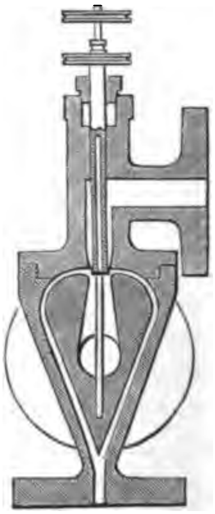
Another arrangement is illustrated by Fig. 156, showing that, instead of both the flat annular surfaces being fixed at a certain distance apart, the upper disc is made with a hollow spindle, through which a rod passes, and is worked by means of the pulley. A hand wheel is keyed on the hollow spindle, which, when turned round the distance between the discs, can be made either greater or less to a nicety through the intervention of the screwed portion. This hollow spindle, passing through a stuffing box, and having a groove filled with packing, prevents any passage of steam outwardly, although admitting a free passage for the steam entering through the slots or holes shown. Within the discharge chamber and around the disc an annular projection, in connection with the overflow branch, is formed within a certain distance of another similar projection cast on the other half of the discharge chamber, so that a free slot all round the periphery of the discs, and at some distance therefrom, receives the discharge water, which may be made to issue with great force by turning the hand wheel so as to admit more steam.

Fig. 156.



Barclay's Disc Ejector, as applied as a Condenser, patented in the year 1863.

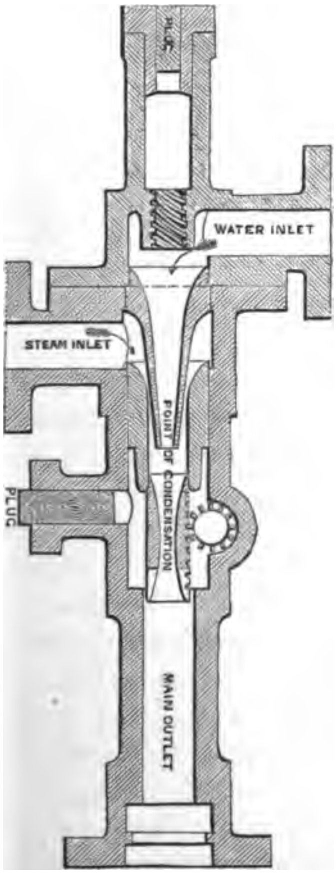
Fig. 157.



Barclay's Cone Ejector, as applied as a Condenser, patented in the year 1863.

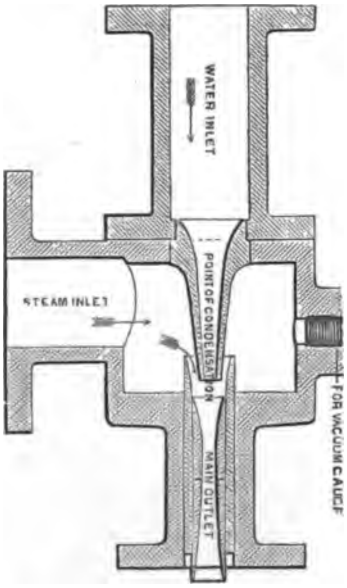
Fig. 157 represents another form of discharge chamber with stationary discs and an adjustable centre piece passing through a hollow spindle of another adjustable disc for regulating the admission of the steam. On turning the hand pulleys, the steam and water may be regulated to the greatest nicety, the one being for the steam and the other for the water.

FIG. 158.



Sheppard's Alteration of the ordinary Giffard's Injector to a Condenser-Ejector, as applied in the year 1867.

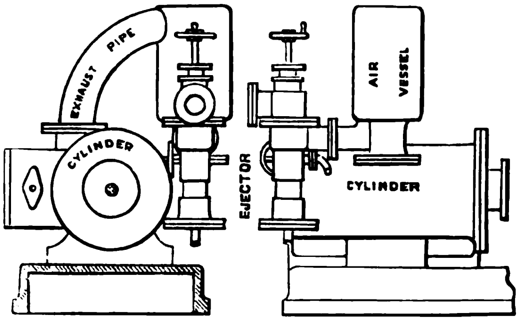
FIG. 159.



Sheppard's Ejector for the condensation of Steam, invented and applied to an engine in the year 1867.

In the early part of the year 1867, Mr. Sheppard of Glamorganshire applied an ordinary Giffard's injector, with suitable pluggings, as a condenser-ejector to an engine, as illustrated by Fig. 158. That being successful, he was induced to construct the more simple arrangement—but the same in principle as the former—as illustrated by Fig. 159, the application of which is shown by Fig. 160.

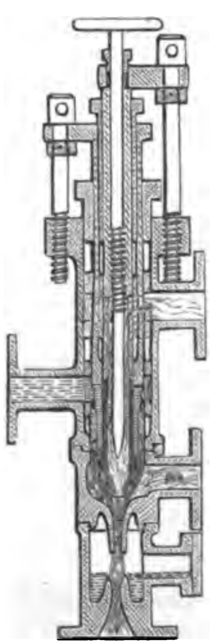
FIG. 160.



Sheppard's arrangement of Engine and Condensing Ejector, applied in the year 1867.

Pressure of Steam in Boiler per square inch	40 lbs.	Stroke of Piston	12 ins.
Temperature of Water in Tank .	56°	Revolutions of Engine per minute .	80
Height of Surface of the Water above the Ejector	6 ft.	Temperature of Discharge Water .	96°
Diameter of Water Jet	$\frac{5}{16}$ in.	Vacuum average	11 lbs.
Diameter of Engine Cylinder . .	6 ins.	Revolutions of Engine per minute .	300
		Temperature of Discharge Water .	102°
		Vacuum average	8 lbs.

FIG. 161.

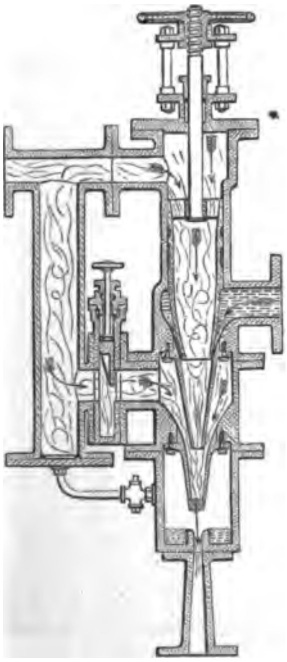


Barclay's Double Nozzle Ejector for the condensation of steam, as applied in the year 1867, and exhibited in the French International Exhibition of that year.

About this time Mr. Barclay stepped forth alone in this matter with his arrangement as shown by Fig. 161, which is an illustration of a double steam nozzle ejector, suitable for two cylinders at the same moment of requirement. He also introduced at that time a slightly different arranged ejector to the previous example, and added a steam chamber to equalise the flow of the steam, as illustrated by Fig. 162.

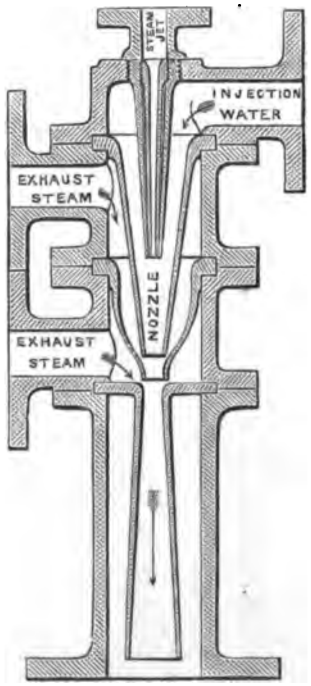
Mr. Morton then came forward as a rival to Mr Barclay—and not as a colleague with him, as in the year 1863—with the arrangement as illustrated by Fig. 163, which shows a double nozzle ejector also, but of a little more simple character than Mr. Barclay's, with the advantages of introducing a steam jet necessary to raise water for the process of condensation on starting the engines, and dispensing thereby with the spindle and its appendages. The main injection water enters at the top side branch, and the steam enters at the two branches below opposite. When the engine has started, the steam-jet can be dispensed with, and the process of condensation carried out by the water passing through the centre of the apparatus and receiving an impulse from the annular jet of steam entering through the top steam-pipe, which produces a vacuum in the lower steam-pipe, and a similar impulse produced from one produces a vacuum in the other pipe, respectively and alternately as the steam escapes from the two cylinders.

Fig. 162.



Barclay's Double Nozzle Ejector for the condensation of steam, fitted with a Steam Chamber to equalize the process of condensing.

Fig. 163.

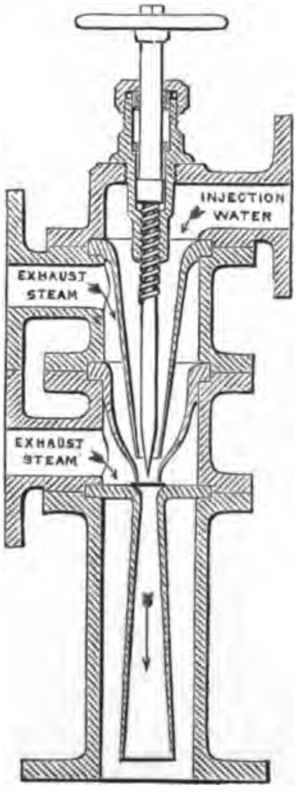


Morton's Double Nozzle Ejector for the condensation of steam, fitted with a Steam Jet Nozzle Pipe to *raise* the injection water, patented in the year 1867.

When a head of water of about seven or eight feet can be obtained, the central steam-jet may be dispensed with altogether, or, when a pump is used for forcing the central jet of water through the jet nozzle and apparatus, it may be advisable or necessary to use a regulating spindle, as shown by Fig. 164, so that it may be adjusted to regulate the inlet flow of water in an annular jet or stream to suit the speed of the water from the pump.

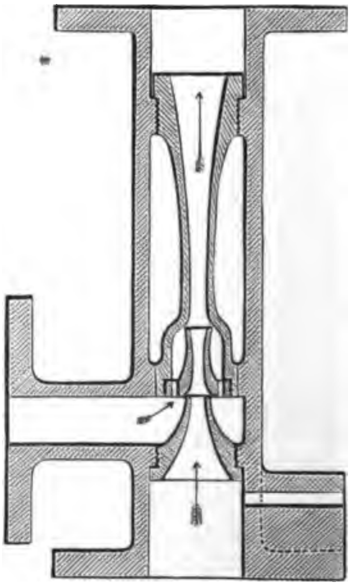
Fig. 165 is a vertical section of a liquid current inducing apparatus, applicable for the raising of water direct through

Fig. 164.



Morton's Double Nozzle Ejector, for the condensation of steam, fitted with a Spindle instead of the "Steam Jet," patented in the year 1867.

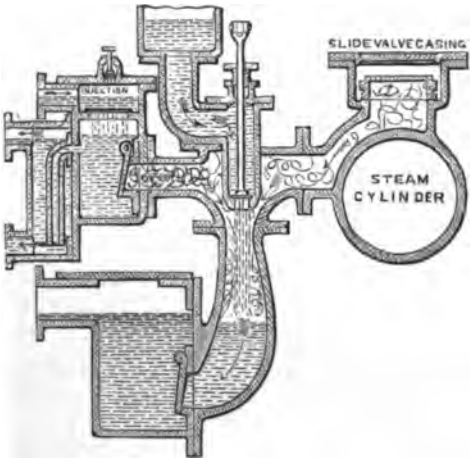
Fig. 165.



Morton's Liquid-Current-Inducing Apparatus, for *raising* water to condense steam, applicable to the Ejectors previously illustrated, patented in the year 1867.

tubes or pipes, either for supplying a head of water for working the former arrangements, or for raising water generally for the various purposes of condensation. When applied, it may be placed in the main range or length of pipes through which the water is to be raised at any distance above the surface of the water to be raised; within the limits of that required for any ordinary lifting pump; and the height to which that water can be raised in the pipes above it depends wholly on the velocity of the actuating steam used and entering at the side branch pipe, which may be regulated by a valve or cock so as to act with any desired lateral force through the annular narrow jet round the end of the central nozzle, through which the water passes from the main pipe in a cylindrical stream or column forced and drawn in through the short induction central tube or nozzle by the said annular jet of steam, and thence up through the main long induction tube or pipe; the small induction tube by preference being cased as shown, the small portion of condensed steam on the outer surface of the tube is forced through the annular slit or jet at its end into the neck of the induction tube, which expands in area in an increasing curve. A lateral branch pipe is made to lead into the main water pipe opposite and close below the nozzle, which is to be fitted with a cock for experimental purposes when required.

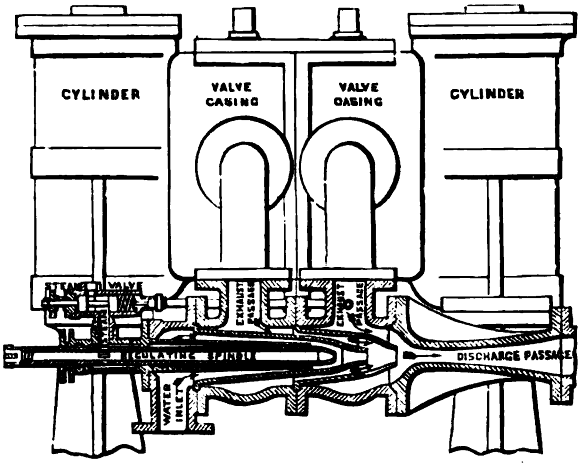
FIG. 166.



Barclay's Arrangement of Ejector, Condenser, and Appendages, with a *working* Injection Valve, as applied to the Cylinder of his Foundry Engine in the year 1868.

The next example we refer to is by Mr. Barclay, as illustrated by Fig. 166, which is a sectional elevation of the ejector and appendages as constructed and applied by him to his foundry engine in the year 1869. The working of the apparatus is that the spindle or injection-valve is opened slightly during each completion of the stroke of the cylinder-piston, sufficiently to admit water enough to condense the steam and form a vacuum. This valve is worked by an eccentric and suitable gear. The cistern on a level with the slide valve is fitted with an injection water spray-plate, and a clack valve below it, that opens or closes a communication with the point or position of condensation directly under the spindle or injection valve; and thus, when the clack valve opens, the water behind it is heated and used as feed water for the boiler. The cistern below the other is the hot well, fitted with a clack or non-return valve also.

Fig. 167.



Morton's Arrangement of Ejector fitted to Inverted Direct-Acting High-Pressure Engines, for the condensation of the steam, in the year 1868.

In the same year, 1868, Mr. Morton made some practical experiments in these matters, and Professor Rankine reported on them in the following manner:—

"Report of Experiments on Engines at Albert Works, Glasgow.—The ejector-condenser was applied, as illustrated by Fig. 167, to a pair of vertical inverted direct-acting steam engines, which exerted collectively a power averaging about

24 indicated H.P. The nominal power of these engines is collectively 7 H.P., if we apply the ordinary rule for low-pressure engines, or 15 H.P. if we apply the ordinary rule for high-pressure engines. The dimensions of the engines and of the condensing apparatus, and the results of the experiments, are given in detail in the first table; but as regards the engines, it may be convenient to state here that their two cylinders were of 18 in. stroke, and about 10¼ in. diameter, that they ran at from 93 to 140 revolutions per minute, and that the steam-pressure gauge indicated from 30 to 40 lbs. on the square inch above the atmospheric pressure, which at the time was 14·75lbs. on the square inch. It may be remarked that the experiments throw light on other questions besides the efficiency of the new condenser; and in particular, that the accurate measurement of the quantity of condensation water, and of its change of temperature, affords the means of calculating the total expenditure of steam, and comparing it with the quantity of steam effectively used in doing work, as indicated by the diagrams.

The principle of the invention may be described as follows: —In every injection condenser the cold water rushes into the vacuum with a velocity of 43 or 44 feet per second, or thereabouts. The exhaust steam rushes from the cylinders into the condenser with a velocity which is many times greater than that of the water. In the common condenser those rapid motions of the water and of the steam are completely checked, and their energy is wasted in agitating the fluids in the condenser, and ultimately in producing heat; and hence it becomes necessary to use an air-pump in order to extract the water, air, and uncondensed steam from the condenser. The power expended in working a well-proportioned and well-constructed air-pump is known by experiment to be equivalent to that which would overcome a back-pressure on the steam-piston of from ½ lb. to ¾ lb. on each square inch of its area, or on an average about 0·6 lb. on the square inch; and that amount of power is lost through the wasting of the energy with which the jets of water and steam rush into the condenser. In the ejector-condenser the motion of those jets meets with no interruption; and its energy is found to be sufficient, without any assistance from pumps, to carry all the water, air, and uncondensed steam—if any—completely out of the condenser and into the hot well, and thus to save the power which would be required to drive an air pump.

The principal parts of the condensing-apparatus on which my experiments were made may be summarily described as follows:—The cold water passes from the tank to a conoidal nozzle; the area of the orifice of that nozzle is about equal to that of the injection sluice of a common condenser suited for the same engine: that is to say, about $\frac{1}{250}$th part of the collective area of pistons. Enveloping the cold water nozzles are a second and a third nozzle of nearly similar figure; these bring the exhaust steam from the two cylinders respectively. The middle nozzle has an orifice a little larger than that of the innermost, or cold water nozzle: the outermost nozzle ends in a throat or contracted vein, a little larger still, beyond which is a gradually widening trumpet-shaped mouthpiece, leading to a pipe which ends at the hot well.

The condensation of the steam takes place in the interval between the orifice of the cold-water nozzle and the throat of the outermost nozzle.

The completeness and efficiency of the condensation were tested by vacuum gauges and by indicator diagrams. By both means of testing, the left-hand cylinder, which exhausted into the middle nozzle, showed a rather better vacuum than the right-hand cylinder, which exhausted into the outermost nozzle. The average results of the whole of the experiments were as follows:—

Mean vacuum shown by gauges, in inches of mercury . .	24·5
Ditto, ditto, in lbs. on the sq. in. . .	12·0
Mean vacuum in cylinders, during return stroke, as shown by the indicator diagrams; lbs. on the sq. in.	10·7
Which, being subtracted from the atmospheric pressure at the time	14·75
Leaves, as the mean back-pressure in the cylinders during the return stroke, in lbs. on the sq. in.	4·05

The back pressure in different experiments ranged between 3 and 4½ lbs. on the square inch. These results are at least as good as the average results as to vacuum and back pressure obtained by means of the common condenser; and they show the condensation of the steam and expulsion of the water, air, and vapour, to be at least as complete and efficient.

I have estimated the saving of power through the dispensing with an air-pump as being equivalent to the doing away with a resistance of 0·6 lb. per square inch area of steam-pistons; and I find it to be on an average of the several experiments just one horse-power, being about 4 per cent. of the mean indicated power of the engines.

I have calculated the energy of the jet of cold water, and I find it to be about ¾ of a horse-power. This forms the greater part of the energy which is wasted in the common condenser, rendering an air pump necessary.

The experiments then, so far as they have gone, lead to the following conclusions:—

First. That the action of the ejector-condenser is at least as efficient as that of the common condenser, with its air pump; and

Secondly. That by the use of the ejector-condenser the power required to drive the air pump is saved.

I have calculated—as the following Tables show—the total quantity of steam expended from its effect on the temperature of the condensation water; and it proves to be on an average about *two and a half times* the quantity which performs work in the cylinder, as calculated from the indicator diagrams. When applied to engines that are free from this defect, it may confidently be expected that the new condensing apparatus will give, as regards vacuum and back pressure, results surpassing even the very good performance which has been described.

TABLE OF EXPERIMENTS

MADE ON THE 27TH OCTOBER, 1868, ON A PAIR OF ENGINES AT THE WORKS OF MESSRS. NEILSON BROTHERS.

CYLINDERS.

Area of each, allowing for piston rods, about	80 sq. ins.
Stroke	1·5 foot

COLD WATER NOZZLE.

Diameter	$\frac{13}{16}''$ = ·8125″
Area	·638 sq. in = ·00443 sq. ft.

WATER TANK.

Area	8′ × 3½′ = 28 sq. ft.
Mean depth of surface below level of nozzle	5·25 feet

WASTE WATER NOZZLE.

Diameter of throat	$\frac{15}{16}''$ = ·9375″
Area of throat	·690 sq. in. = ·00479 sq. in.
Diameter of mouthpiece	3·0″
Area of mouthpiece	7·07 sq. ins. = ·0491 sq. ft.

COLD WATER SUPPLY.

Mean rate of flow in cubic feet per minute	28′ × ·41 = 11·48 = 716·4 lb.
Ditto ditto per second	·1913 = 11·94 lb.
Velocity of cold water through nozzle, feet per second	$\frac{\cdot 1913}{\cdot 00443}$ = 43·2

	Feet.		Lbs. per sq. in.
Head due to that velocity	29	=	12·57
Add mean height to which water is lifted	5·25	=	2·275
Total head	34·25	=	14·845

Temperature	47° Fahr.

Mean work per minute done in raising and propelling water-jet, exclusive of friction . . . . 716·4 × 34·25 = 24537 ft. lbs. = ·744 I.H.P.

BAROMETER.

30·05 inches mercury = 14·75 lbs. on the square inch.

Sets of Experiments.	A.	B.	C.	D.	E.
	Rt. Hand Cylinder.		Left Hand Cylinder.		
Nos. of diagrams	1	2·3 4·5	6	7·8	9
Revolutions per minute	130	93	abt. 140	107	108
Steam-gauge above atmosphere, lbs. on the square inch	34	from 32 to 38	...	35	from 40 to 30
Do., do., absolute	48·75	fr. 46·75 to 52·75	...	49·75	fr. 54·75 to 44·75
Vacuum-gauges below atmosphere, lbs. on the square inch. *	12·03 11·54	12·4 12·1	... ...	12·3 11·8	... ...
Do., do., absolute	2·72 3·21	2·35 2·65	... ...	2·45 2·95	... ...
Mean back pressure	4·25	3·12	4·50	4·38	4·
Absolute pressure of release	10·75	10·80	8·75	12·00	10·50
Initial absolute pressure	42·75	38·25	32·75	42·75	42·75
Mean effective pressure	15·25	14·83	9·85	16·78	15·90
Mean absolute pressure	19·50	17·95	14·35	21·16	19·90
Temperature of waste water (Fahrenheit)	86·5°	80·5°	...	88·0°	91·0°
Elevation of temperature above cold water	39·5°	33·5°	...	41·0°	44·0°
Heat carried off by water, British units per minute	28298	23999	...	29372	31522
Velocity of pistons, feet per minute	390	279	420	321	324
Load of one piston, lbs.	1220	1186·4	788	1342·4	1272
Indicated work of one cylinder, ft. lbs. per minute	475800	331006	330960	430910	412128
Do., do., two cylinders	951600	662012	661920	861820	824256
Indicated horse-power	28	20	20	26	25
Indicated work per minute reduced to equivalent quantity of heat	1233	858	858	1116	1068
Total expenditure of heat, British units per minute	29531	24857	...	30488	32590
Efficiency of engines	·042	·035	...	0·037	·033
Volume of steam exhausted as shown by indicator in cubic feet per minute	433	310	467	357	360
Volume of 1 lb. in cubic feet	35	35	43	32	36
Weight of steam shown by indicator in lbs. per minute	12·4	8·9	10·9	11·2	10·0
Temperature of steam at end of stroke (Fahrenheit)	197°	197°	187°	202°	196°
Total heat per lb. of that steam from temperature of waste water	1087	1093	...	1086	1082
Heat of condensation of steam indicated	13479	9728	...	12163	10820
Heat carried off by waste water (as before)	28298	23999	...	29372	31522
Actual expenditure of steam in lbs. per minute, as calculated from heat of waste water	26·	22·	...	27·	29·1
Proportion in which steam actually condensed exceeds indicated steam	2·10	2·47	...	2·41	2·91
Work in ft.-lbs. per minute saved by dispensing with the air-pump, estimated as equivalent to 0·6 lb. pressure per square inch of steam piston	37440	26784	40320	30816	31104
Do., indicated horse-power	1·13	·81	1·22	·93	·94

---

* First result is for left hand, and second result for right hand engine.

ABSTRACT OF PRINCIPAL MEAN RESULTS.

Mean power saved by dispensing with air-pump, indicated H.P.	1·0
Mean indicated H.P. of engines	23·8
Mean back-pressure in cylinders, lbs. on the sq. inch	4·05
Mean vacuum in cylinders, ditto, ditto	10·7
Mean vacuum shown by gauges, ditto, ditto	12·0
Ditto, ditto, ditto, in inches of mercury	24·5
About two-thirds of the indicated power were due to the vacuum in the cylinders.	
Temperature of the cold water	47° F.
Mean temperature of waste water	83½° F.
Mean increase of temperature	36½° F.

The condenser was about 5 feet above the tank from whence the water was drawn; so that the water had to be lifted to that extent. In calculating the pressure due to the velocity *plus* that of 5 feet of water, the sum was found to be a little greater than the atmospheric pressure of 14·75 lbs. upon the inch. This must have been caused by the impulse of the steam aiding the atmospheric pressure in accelerating the jet.

REPORT OF EXPERIMENTS AT RYESHOLM PIT, NEAR DALRY, AYRSHIRE.—The engine on which the following experiments were made is a single-cylindered double-acting horizontal steam engine. It drives a fly-wheel shaft, which, by means of suitable gearing, and a pair of bell-crank levers, works a pair of pumps for raising water from a pit. The work done by the engine at a given speed is thus practically constant. During the experiments a uniform speed of 22 revolutions per minute was kept up; and the indicated horse-power was 24½. The cylinder is without a steam jacket; consequently some heat is wasted through condensation and re-evaporation in the cylinder, which might be saved if there were a jacket. Throughout the experiments the engine was worked at full steam, the admission going on from the beginning to the end of the stroke. The diagrams taken show a fall of pressure at the end of the stroke to the extent of about 3 lbs. on the square inch, below the initial pressure; and this is one of the effects of condensation in the cylinder. They also show a gradual formation of the vacuum, during the earlier part of the return stroke; and this is an effect of the re-evaporation of water previously liquefied in the cylinder, through the want of a steam jacket. The engine was originally non-condensing, and was converted into a condensing engine by the addition of an ejector-condenser.

Principal Dimensions of the Engine.

Stroke	4½ feet.
Diameter of cylinder	18 inches.
Area of piston (allowing for half piston rod).	252 square inches = 1·75 sq. feet.
Space swept by piston per revolution	15·75 cubic feet.
Space swept per minute, at 22 revolutions	346·5 cubic feet.
Mean speed of piston, at 22 revolutions per minute	198 feet per minute.

General Description of the Experiments.—The engine being kept working at the before-mentioned steady speed of 22 revolutions per minute, the quantity of water discharged from the condensing apparatus was measured by means of a suitable gauge; and the rise of temperature of that water was ascertained by comparing together two thermometers, one in the cold well and the other in the hot well. Thus were obtained data for calculating the total expenditure of steam, from its heating effect on the condensation water. Indicator diagrams were also taken to show the power, and the pressure and vacuum in the cylinder when working as a condensing engine. The exhaust pipe of the cylinder was then disconnected from the condensing apparatus, and made to discharge the exhaust steam into the air. The engine was thus made to work as a non-condensing engine, at the same speed and against the same load as formerly; and indicator diagrams were taken to show the pressure in the cylinder under these circumstances. All the diagrams showed the same mean effective pressure, viz., 16·2 lbs. on the square inch; and the same power, viz., 24½ I.H.P. The boiler pressure, as shown by the steam gauge, ranged from 29 to 32 lbs. on the square inch above the atmosphere; but in all the experiments, whether with or without condensation, the pressure in the cylinder was greatly reduced by means of the throttle valve. The vacuum gauge, when condensation was used, remained perfectly steady at 24 inches = 11·76 lbs. on the square inch;

and this is sensibly identical with the greatest vacuum shown by each of the diagrams.

Experiments made without Condensation.

Initial pressure of steam; lbs. on the square inch above atmosphere	19·
Final pressure, ditto, ditto, ditto	16·
Weight of steam expended in lbs. per hour, as calculated from final pressure in cylinder	1578·
Ditto, in lbs. per I.H.P. per hour	64·4
Weight of steam expended in lbs. per hour, as calculated from initial pressure in cylinder	1731·
Ditto, ditto, per I.H.P. per hour	70·7

Experiments made with Condensation.

Initial pressure of steam; lbs. on the square inch above atmosphere	9·
Final pressure, ditto, ditto, ditto	6·
Vacuum at end of exhaust, lbs. on the square inch	11·7
Weight of steam expended in lbs. per hour, as calculated from final pressure in cylinder	1086·
Ditto, ditto, per I.H.P. per hour	44·3
Weight of steam expended in lbs. per hour, as calculated from initial pressure in cylinder	1234·
Ditto, ditto, per I.H.P. per hour	50·3

Hence it appears that when the expenditure of steam is computed from the indicator diagrams, it is found to be reduced by the addition of the condensing apparatus to about *seven-tenths* of its previous amount, when the engine is doing the same work: in other words, the saving is 30 per cent.

Results of Experiments on the Condensation Water.—The quantity of water discharged from the condensing apparatus was gauged by causing it to pass out of a tank through an accurately turned and measured circular orifice in a thin plate of sheet iron, and measuring the height above the centre of that orifice at which the surface of the water in the tank stood. The following are the data and results:—

Diameter of the orifice, inches	3·5
Total area, in fractions of a square foot	·06682
Effective area, the co-efficient of contraction being ·618	·0412
Head of water in tank	1¼ foot
Velocity at contracted vein produced by that head, feet per second	9·03

Discharge, cubic feet per second	·372
Ditto, ditto, per minute	22·32
Ditto, ditto, per hour	1339·2
Ditto, lbs. per hour	83430·
Temperature, cold well	52° Fahr.
Ditto, hot well	70° Fahr.
Difference	18° Fahr.
Units of heat (British) per hour given by the steam to the water, very nearly	1,502,000
Total heat of steam from 52° at 230°—being the temperature corresponding to final pressure in cylinder—British units	1,131
Total steam condensed in lbs. per hour, as calculated from effect on water of condensation	1328·
Ditto, per I.H.P. per hour	54·2

The excess of the total expenditure of steam, as thus computed, above the expenditure as shown by the diagrams, is to be accounted for mainly by condensation and re-evaporation in the cylinder, which go on in all engines not provided with steam jackets.

FURTHER COMPARISONS OF EXPENDITURE OF STEAM. — The calculations of the expenditure of steam in pounds per hour, and in pounds per indicated horse-power per hour, with and without condensation, are here recapitulated :—

WITH CONDENSATION.	Lbs. Steam per Hour.	Lbs. Steam per I.H.P. per Hour.
A. Calculated from final pressure, as shown by diagram	1086	44·3
B. Calculated from initial pressure, as shown by diagram, the fall of pressure during admission being ascribed to liquefaction in the cylinder	1234	50·3
C. Calculated from effect on temperature of water discharged	1328	54·2
WITHOUT CONDENSATION.		
D. Calculated from final pressure, as shown by diagram	1578	64·4
E. Calculated from initial pressure, as shown by diagram, the fall of pressure during admission being ascribed to liquefaction in the cylinder	1731	70·7

The difference between the numbers marked *B* and *C* in the preceding table—viz., 94 lbs. per hour, or 3·9 lbs. per indicated horse-power per hour, being 7 *per cent.* of the total expenditure of steam marked *C*—represents the quantity of steam lost, or ineffectively expended, through the following causes:—

1. Filling cylinder-ports and clearance.
2. Liquefaction immediately on entering the cylinder—followed by re-evaporation during return stroke.
3. Leakage past the packing of the piston.
4. Expenditure at the starting-jet of the condensing apparatus.

It is evident, however, that the first three causes alone are sufficient to account for the whole, or nearly the whole, of a waste of steam amounting to seven per cent. of the whole expenditure; and this is in accordance with the fact that, during the working of the engine, the cock of the starting-jet is kept so nearly closed that the escape through it must be almost inappreciable, being just sufficient to prevent the suction of air at the small hole in the cylinder of the self-acting piston-valve, by which the starting-jet is regulated.

When the engine was worked without condensation, there were no means of measuring the total expenditure of steam, including waste, as there were when condensation was used. If we assume, however, an allowance which is commonly made in practice for clearance, leakage of piston, packing, &c., viz., 5 per cent., we obtain the following *probable* estimate of the total expenditure of steam *without condensation*:—

	Lbs. Steam per Hour.	Lbs. Steam per I.H.P. per Hour.
E. Expenditure, as already calculated from initial pressure	1731	70·7
Add 5 per cent. for clearance, leakage, &c.	87	3·5
F. Probable total expenditure without condensation . .	1818	74·2
G. Total expenditure with condensation, as before . .	1328	54·2
Difference, being net saving by the use of the ejector-condenser	490	20·0

Being 27 per cent. of the greater expenditure. This, however, is probably a low estimate of the saving; for it is based on a low estimate of the waste of steam in the non-condensing engine.

Useful Work.—The useful work done by the engine is calculated from the following data:—

Diameter of bucket of each of the two pumps	10½ inches.
Stroke	4 feet.
Height of lift . . . 25 fathoms	= 150 feet.
Double strokes per minute, $\frac{5}{9}$ths of number of revolutions of engine, or	$12\frac{2}{9}$

The results are:—

Work, foot-lbs. per minute	550,368
Effective horse-power	16·68
Indicated horse-power, as already stated	24·5
Efficiency, or ratio of effective to indicated power	0·68

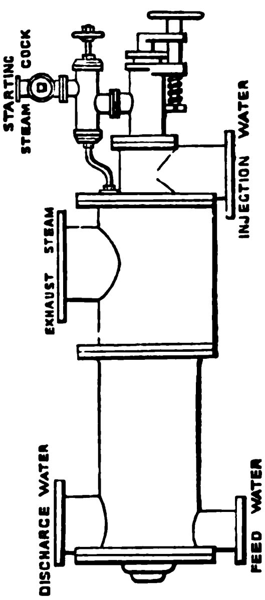
That is to say, 34 per cent. of the indicated power is the power expended in overcoming the friction of the pistons, valves, mechanism of engine and pumps, and pump plungers, and the resistance of pipes and valves to the motion of the water raised by the pumps.

Conclusions.—The principal conclusions to be drawn from the experiments are, that the use of the ejector-condenser effects a saving of steam, as compared with the expenditure of steam by the same engine when doing the same work without condensation, which certainly amounts to 27 per cent., and probably to 30 per cent.: that there is probably a greater proportionate saving in the fuel burned; for it is well known that a diminution in the absolute quantity of fuel burned in a boiler increases the proportionate evaporative power of the fuel, by diminishing the waste of heat: that there is a steady vacuum of 24 inches of mercury, or 11·75 lbs. on the square inch: that the expenditure of steam by the starting-jet is certainly very small, and probably almost inappreciable: that the condensing apparatus is easily manageable, and not liable to get out of order: and that it has been added to the engine without requiring any addition to the size of the engine-house, and without causing any inconvenience by the space which it occupies there.

It may be remarked that the present example of the ejector-condenser, having been originally intended for a larger engine, discharges a quantity of water greater than is absolutely necessary for the condensation of the steam, and therefore at a lower temperature than if the condenser had been specially designed for the engine; and that it therefore does not show the advantages of the ejector-condenser to their full extent.

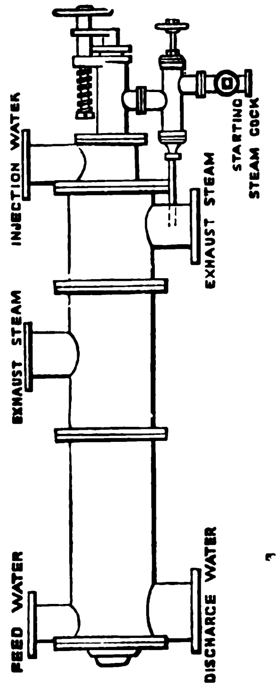
Mr. Morton patented two very simple arrangements of single and double nozzle ejectors, as illustrated by Figs. 168 and 169, in complete views, and a sectional view of the latter by Fig. 170.

Fig. 168.



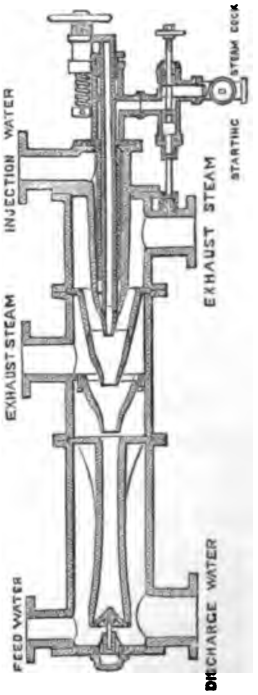
Complete Elevation of Morton's Ejector for the condensation of steam from Single Cylinder Engines.

Fig. 169.



Complete Elevation of Morton's Ejector for the condensation of steam from two Cylinder Engines.

Fig. 170.



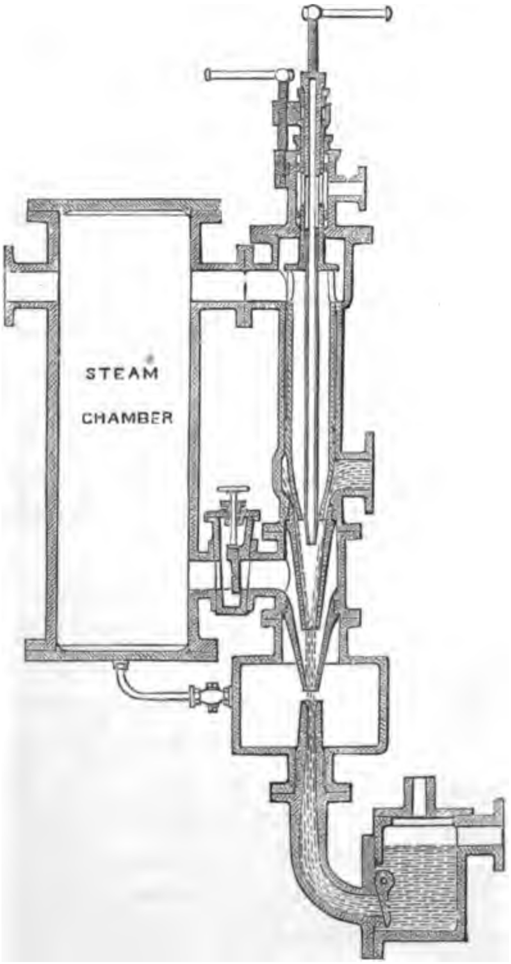
Sectional Elevation of Morton's Ejector for the condensation of steam from two Cylinder Engines.

In starting these ejector-condensers the large hand-wheel should be turned so as to raise the central spindle, and thereby open the water nozzle.

The small wheel should be screwed down so as to keep open the starting steam-jet until the engine is fairly at work.

Prior to starting the engine, open the steam stopcock, and the injection water will then pass through the apparatus and thereby form the vacuum.

FIG. 171.

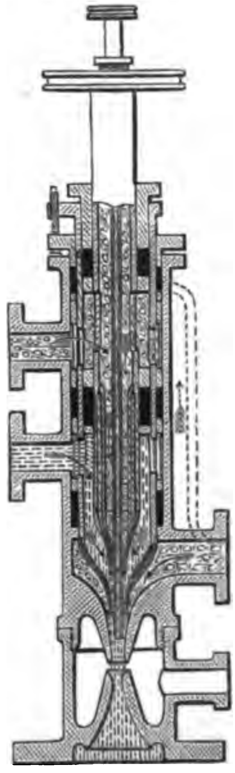


Barclay's Ejector-Condenser, fitted with a Central Jet Steam Pipe, to be used on starting the Engine in the place of the Side Jet Pipe, as shown by Fig. 170, patented in the year 1869.

So soon as the engine is working at its usual velocity, the small wheel should be unscrewed, so as to allow the vacuum to automatically shut off the starting steam-jet.

Mr. Barclay not having exhausted his ideas on this subject, he patented in the year 1869 the arrangement of ejector and apparatus as illustrated by Fig. 171, which is a sectional elevation of the ejector and steam-chamber to which it is connected, the top branch on the left hand being in connection with the exhaust pipe of the engine cylinder. The ejector-condenser is shown in operation, and the central pipe, which communicates to the boiler by the top-side branch, is therefore lowered by means of the screw into a working position; in this case it is shown as projecting into the combining, or lowest nozzle. The branch is provided with a stopcock, not shown in the illustration, by which the steam from the boiler can be shut off and admitted as required.

Fig. 172.



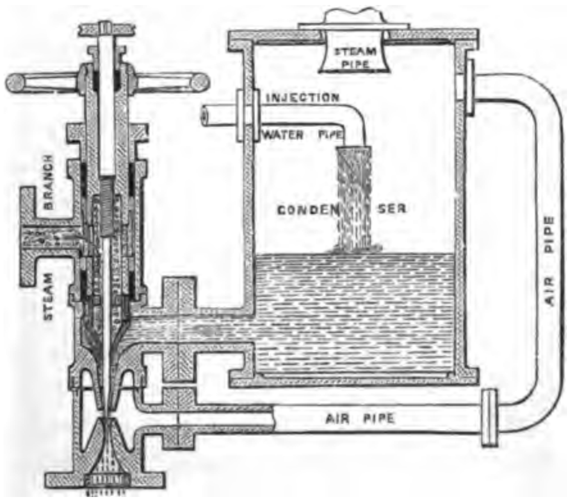
Sectional Elevation of Barclay's Double Nozzle Central Steam Jet Ejector-Condenser in full work, patented in the year 1869.

The illustration, Fig. 172, is another of Mr. Barclay's arrangements of the central steam-jet ejector, and illustrates also the passage of the steam and water during the process of condensation.

Mr. Barclay patented within the same year the application of an ejector in substitution for an air-pump for drawing off the injection water, water of condensation, and the air from an ordinary condenser, as illustrated by Fig. 173. The ejector is connected to the lower part of the condenser by the branch, and the overflow chamber is connected to the upper part or air space of the condenser by the air pipe. Sufficient steam to put the ejector into operation is admitted into the apparatus by the top branch; when therefore the apparatus is in action, the injection water passing in through and lodging in the condenser is withdrawn through the branch passage, and the air and uncondensed vapour from the upper part of the condenser are withdrawn by the rushing action of the water-jet through the air pipe. In this manner the injection-water, water of condensation, uncondensed vapour, and air are all ejected through the discharge-throat of the ejector.

Mr. Morton patented also various arrangements which, although of great similarity, warrant distinction. The first of this class is shown by Fig. 174, on the next page, illustrating that the exhaust steam from the engine cylinder enters the condensing apparatus by the left-hand branch, and is directed as shown by the arrow towards the throat of the inducing tube. The injection or inlet water enters by the right-hand branch, and is also directed by the form of the inlet nozzle in a central or annular jet or jets towards the inducing tube; and at each discharge of the exhaust steam from the cylinder or cylinders the jet of water receives an impulse from the exhaust steam, which is more than sufficient to propel it through the inducing tube against the pressure of the atmosphere. Between each alternate discharge of exhaust steam from the cylinders of slow going engines especially, the jet of water may not have sufficient force imparted to it to enable it to pass through the inducing tube; then, in that case, it returns by the side passage and conical annular space again through the

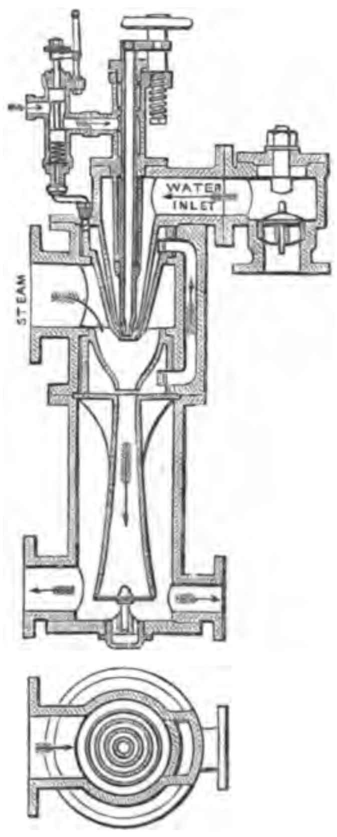
FIG. 173.



Barclay's Central Plug Ejector, connected to an ordinary Injection Condenser as a substitute for an Air Pump, patented in the year 1869.

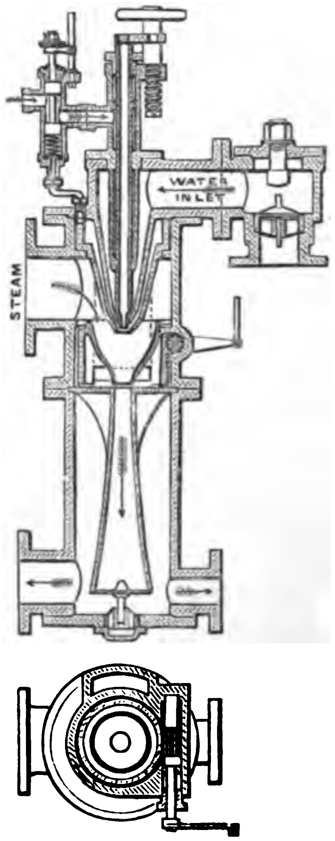
return water jet nozzle, which is formed of nearly the same diameter as the inlet water nozzle, and at such a distance in front of it that the area of the annulus between the two nozzles nearly equals the area of the smallest diameter of the return water nozzle. The return water, whilst passing through the outer nozzle, therefore for the time being, stops the inlet flow of water through the next inner nozzle, until the next discharge of exhaust steam from the cylinder gives the water a sufficient force to pass through the inducing tube, and this manner of returning

FIG. 174.



Morton's Single Branch Central Steam Jet Ejector, fitted with Steam-Regulating and Non-Return Water Valves, patented in the year 1869.

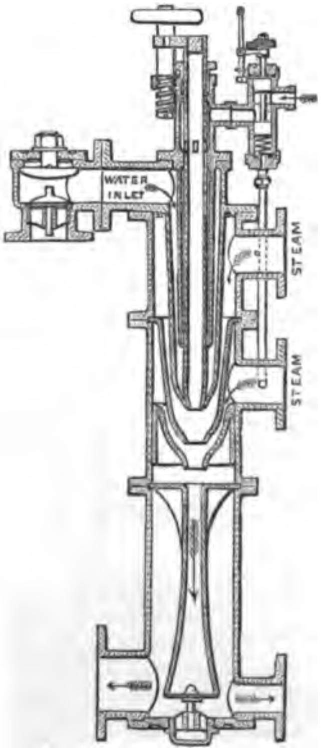
FIG. 175.



Morton's Ejector, as shown by Fig. 174, fitted with a Rack and Pinion to regulate the Combining Nozzle, patented in the year 1869.

the water and alternately stopping its inlet flow during the interval between the discharges of steam from the cylinders form the chief improvements in this modification or arrangement of the parts. To prevent the possibility of the injection or inlet water flowing or returning back through the injection pipe, a non-return valve is fitted on the suction side of the apparatus, and for a similar reason a valve is fitted at the lower end of the inducing tube, so that the discharge water can never return back through the apparatus.

FIG. 176.

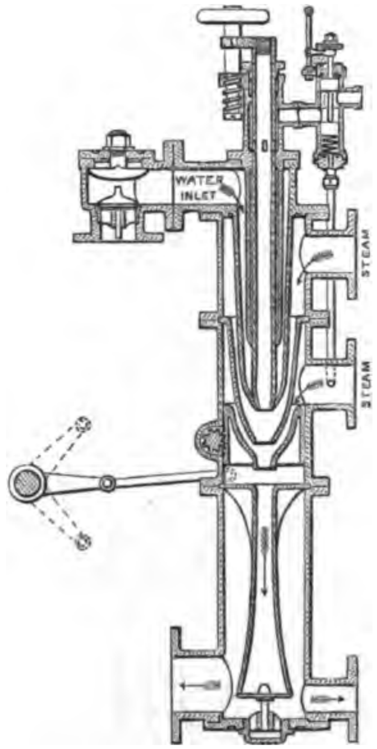


Morton's Ejector-Condenser, as arranged for two Cylinders with a Self-Acting Combining Nozzle, patented in the year 1869.

Fig. 175 is a vertical and a horizontal section of another modification of a similar apparatus, with the addition of making the outer or last steam and water combining nozzle adjustable by means of the rack and pinion connected with the governor of the engine through the lever and rod, so that when the engine increases in speed the combining nozzle becomes adjusted at a greater distance from the water nozzle in accordance therewith.

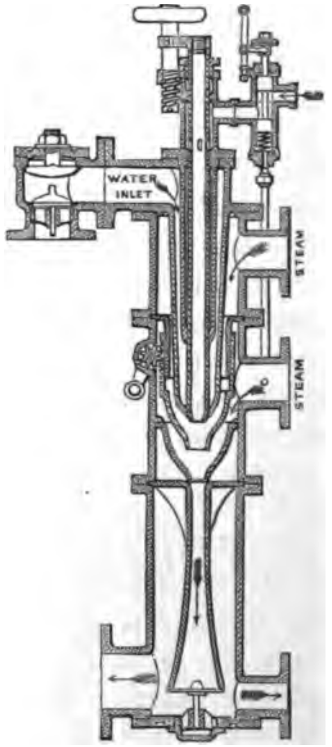
Fig. 176 is a sectional elevation of another modification, as adapted to a pair of cylinders with separate exhaust pipes, the exhaust steam from one cylinder entering the apparatus by the top branch, and that from the other by the lower branch. The chief feature in this modification differing from the previous modifications shown by Figs. 174 and 175, consists in making the combining nozzle self-acting, or automatic; thus, when the jet of water passing through the two outer nozzles is insufficient in force to pass through the inducing tube, it gathers in the space between the combining nozzle and the throat of the apparatus or inducing tube, and thereby produces a force capable of moving the combining nozzle nearer to the water nozzle, and by so doing it increases the impulsive force of the exhaust steam, so that the water jet is propelled through the inducing tube with sufficient force, not only to discharge itself, but by its inducing action to drag with it that which had gathered in the surrounding space, thereby producing a diminished pressure on the combining nozzle, when it again recedes from the water nozzles to its maximum working position.

FIG. 177.



Morton's Steam Double Branch Ejector-Condenser, fitted with a Rack and Pinion to regulate the lower Combining Nozzle, patented in the year 1869.

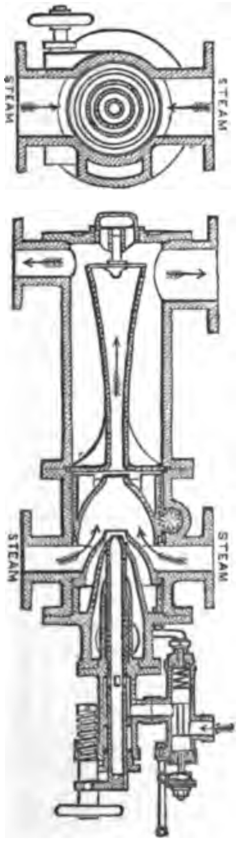
FIG. 178.



Morton's Steam Double Branch Ejector-Condenser, fitted with a Rack and Pinion .to regulate the upper Combining Nozzle, patented in the year 1869.

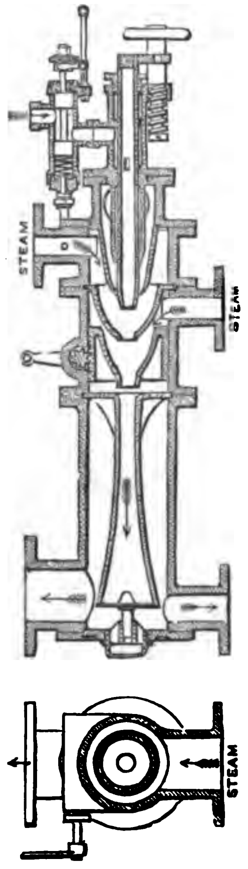
Fig. 177 is a similar section of a similar apparatus to that previously shown and described, but instead of the combining nozzle being self-acting, as in Fig. 176, it is worked by a rack pinion and lever in connection with a lever keyed upon the shaft for reversing the link motion of the engines. When the reversing link is in mid-gear the combining nozzle is at its minimum distance from the water nozzles, and when the reversing link is in full gear, in either direction for running the engines forward or back, then the combining nozzle is at its maximum distance from the water nozzles, thus causing the combining nozzle to bear a constant relation to the position of

FIG. 179.



Morton's Ejector-Condenser, fitted with Rack Gear and a Side Passage, patented in the year 1869.

FIG. 180.

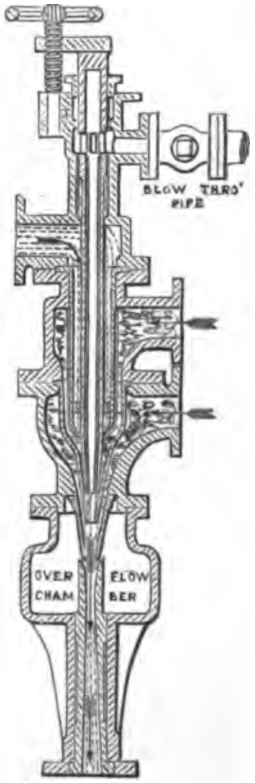


Morton's Separate Combining Nozzles Ejector-Condenser, patented in the year 1869.

the reversing link and quantity of steam admitted to the engines and apparatus.

Fig. 178 is a similar section of another modification of this apparatus, also for a pair of engines. In this modification, the first combining nozzle is made adjustable, instead of the second, as in the two former modifications, which in this case is stationary; otherwise the apparatus and the working of the movable nozzle, or nozzles when more than one is used, are similar to those just described in reference to Fig. 177.

Fig. 181.



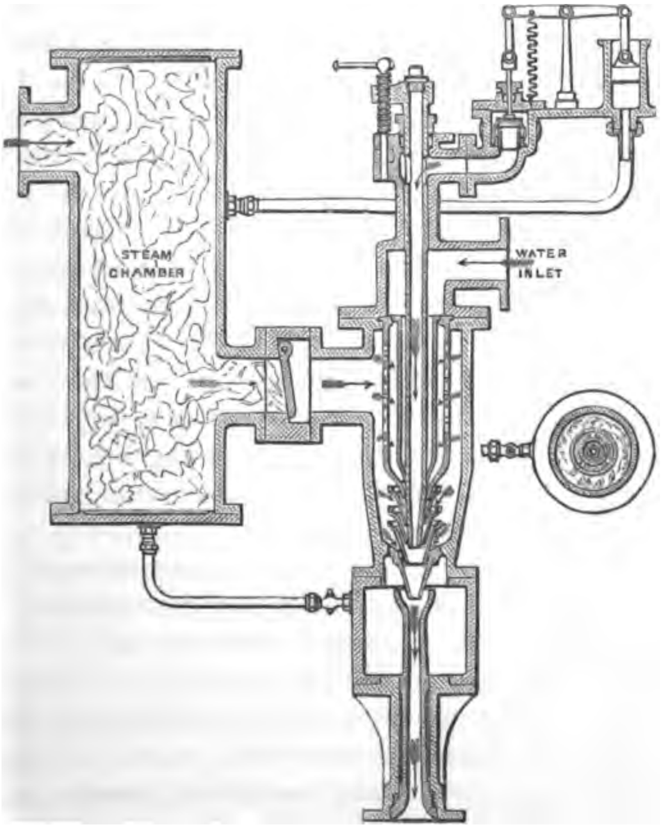
Barclay's Steam Jet and Double Steam Branch Ejector-Condenser, patented in the year 1869.

Fig. 179 is an elevation and plan in section of a modification so arranged that the exhaust steam from a pair of cylinders enters the apparatus respectively from each by the rectangular branches at opposite sides, and acts in one combining nozzle common to both branches and cylinders. The combining nozzle is made adjustable, either regulated by the governor or link motion actuating mechanism, and is formed and fitted with the return passage and a return nozzle.

Fig. 180 is a sectional plan and elevation of a modification of the apparatus, wherein two combining nozzles are used, with the branches for admitting the exhaust steam on each side of the apparatus, in connection with two separate nozzles, and the lower one being worked by a rack, pinion, and lever, which latter is in connection with the engine governor as in the other case.

Mr. Barclay followed immediately after this with his arrangement as illustrated by Fig. 181, showing that there are four nozzles, through the first of which is a blow-through steam jet pipe, and steam from the boiler is admitted, by the branch provided with the stop-cock, down through and beyond the second nozzle into the remaining nozzles. On starting the apparatus into action, and as soon as the steam jet has caused the water to flow, the other steam, which may be either steam direct from a boiler or that coming from an engine or machine wherein it has performed a previous action, or from a vessel or chamber from which it is to be exhausted, is admitted through the two side steam branches, and it acts on the water as illustrated, while the starting jet admitted through the nozzle or blow-through pipe may or may not be wholly or partially shut off by the stop-cock.

FIG. 182.



Barclay's Compound Nozzle Ejector-Condenser, fitted with a Vacuum Valve to regulate the Steam Jet, patented in the year 1869.

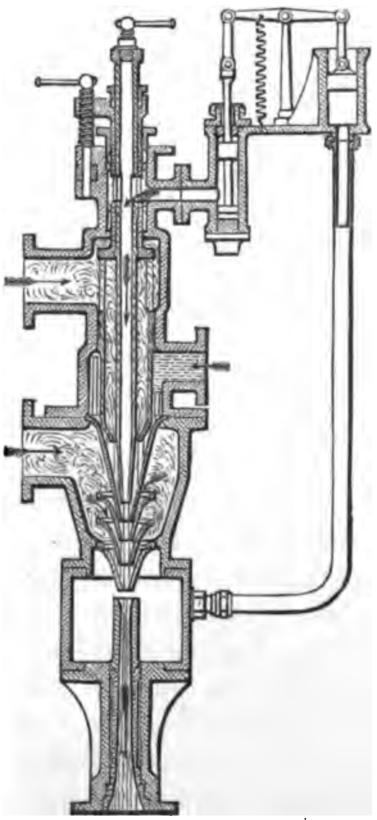
The next illustration, Fig. 182, shows another arrangement of a compound nozzle ejector in connection with a steam chamber. The mechanical arrangement being an important feature in this case, we may explain that on the perforated nozzle, lugs or projecting pieces are cast, and on their outer ends a screw thread is cut, on which the first short nozzle is secured; and on this nozzle lugs or projections are formed, on which the second short nozzle is held, and similarly the third nozzle, the fourth nozzle being fixed into the body of the apparatus as shown. When the nozzles are thus put together, between each of the lugs or projections are spaces as shown by the transverse section, and through those spaces the steam passes from the main branch and reaches the water that surrounds the jet pipe. This pipe is adjustable in position by means of the screw and handle, and is placed in connection with the steam from the boiler by the branch to which the valve box is attached.

This box contains an annular lift valve attached to the spindle and link, and by the lever and rod to the piston in the atmospheric cylinder. The lower part of this cylinder is connected by the pipe to the steam chamber, and a spring connects the lever to the valve cover to which the spring is hooked, and by means of its tension draws the lever downwards and keeps the valve shut, except at such times as it is opened by the atmospheric pressure acting on the piston, namely, when the vacuum in the chamber is reduced too low to maintain the water flowing through the apparatus. At such times the valve, being lifted, allows a little steam from the boiler to flow through the central nozzle or blow-through pipe, and this maintains the water running until sufficient pressure is restored in the steam chamber; it being certain that a very little pressure above zero in the chamber is sufficient to maintain the water in motion, that is to say, a pressure equal to the difference between the partial vacuum formed in the cylinders of the engine and a total vacuum; but when the vacuum approaches too near the total, then the steam coming from the boiler prevents the apparatus from ceasing to act.

The arrows indicate the passage of steam and water through the apparatus, which when in action, the steam flowing from the steam chamber keeps the flap valve open, but when the ejector-condenser is stopped, the atmospheric pressure acting on the water issuing from the lower and main discharge pipe forces it back into the overflow chamber, where there is a vacuum or partial vacuum, and the flap valve being then shut prevents the water from passing into the steam chamber and the cylinders. By this arrangement of the five steam nozzles shown, it is obvious that the water jet issuing from the smaller long nozzle receives a succession of impulses of steam as it is passing through them, and by means of this succession of impulses the water is caused to flow through the final nozzles more efficiently than hitherto. At the same time a greater number or a larger area of condensing surfaces of water are obtained—that is, a condensing surface between each pair of nozzles—than in apparatus of the kind as constructed with four nozzles.

Fig. 183 is a vertical section of an ejector-condenser slightly different in its arrangement from the previous example, as in this case a less number of such nozzles are employed. The blow-through jet pipe is adjustable by the top screw and handle, and the steam nozzle is adjustable by means of the side-screw and handle. Two steam branches are employed, and these may either be attached to a receiving steam chamber, or direct to the engine exhaust pipes. A piston valve

Fig. 183.

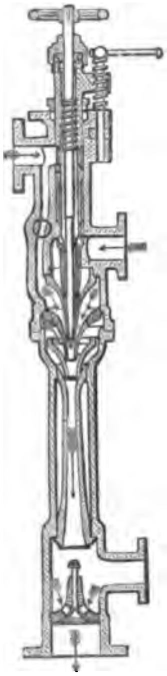


Sectional Elevation of Barclay's Compound Nozzle Ejector Condenser for two Cylinders, illustrating the process of condensation, patented in the year 1869.

is used for admitting steam through the blow-through pipe or central jet nozzle, and it is actuated by means of the piston in the atmospheric cylinder, this cylinder being connected to the overflow chamber by the pipe.

The next example is shown by Fig. 184, and specially illustrates the placing of a stop-cock in the side passage which connects the branch surrounding the long nozzle with the chamber surrounding the steam or shorter nozzle. By this arrangement the water jet is started into action through the nozzles by admitting steam at the top-side branch, which rushes down through the long nozzle so as to flow with the water that is drawn into the apparatus through the lower side branch; and as soon as the water jet is thus put into motion the stop-cock is opened into the position shown, and therefore allows the steam to pass into the lower passage or chamber, into the second short nozzle, and thence through the openings therein into the next short nozzle, and next to ultimately impinge upon the water jet at the final point.

FIG. 184.

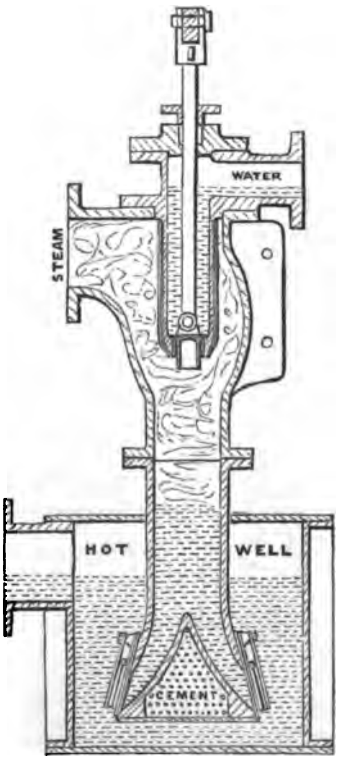


Barclay's Ejector-Condenser, with a Stop-Cock in the Side Passage, and fitted with a Foot-Valve, patented in the year 1869.

By means of this arrangement, the apparatus may be caused to inject or eject a small quantity of liquid, or condense a small quantity of steam, when the stop-cock is shut, or to inject or eject a larger quantity of liquid, or condense a larger quantity of steam, when the stop-cock is open; and another advantage resulting from this arrangement is that it is capable of feeding or injecting a liquid at a much higher temperature than with other apparatus of the class hitherto constructed. The water jet being first heated by the condensation of steam at the end of the long nozzle, it is further heated by the condensation of the steam at the ends of the three short nozzles. This apparatus is provided with an overflow branch; also with a foot valve so shaped as to effect a minimum of resistance to the liquid passing around it, and to shut easily when any reaction takes place, but when used as a condenser. The top side screw is for regulating the position of the long nozzle, and the quantity of steam passing through the nozzle is adjusted in the usual manner by the central spindle.

Mr. Barclay patented also the ejector as illustrated by Fig. 185, the working of which is that the steam passes direct from the exhaust port of the cylinder into the condenser through the branch, escapes down the chamber, and blows out the water contained in the lower part thereof through the flap valves into the surrounding cistern or hot well. These valves, which are four in number, are placed on a valve box, square in plan, with rectangular openings at either side closed by flap valves. The lower part of the valve box is of pyramidal form, with the sides of the pyramid curved as shown, and the hollow underneath is filled in with Portland cement or other material. The flap valves are fitted with stops, so that they may not open more than a fixed distance. These stops may be applied in various forms. At the upper part of the condenser the water branch is connected to a cistern of water not shown, from which the water flows in and fills the top chamber, in the bottom of which the spindle valve is fitted to a corresponding seat.

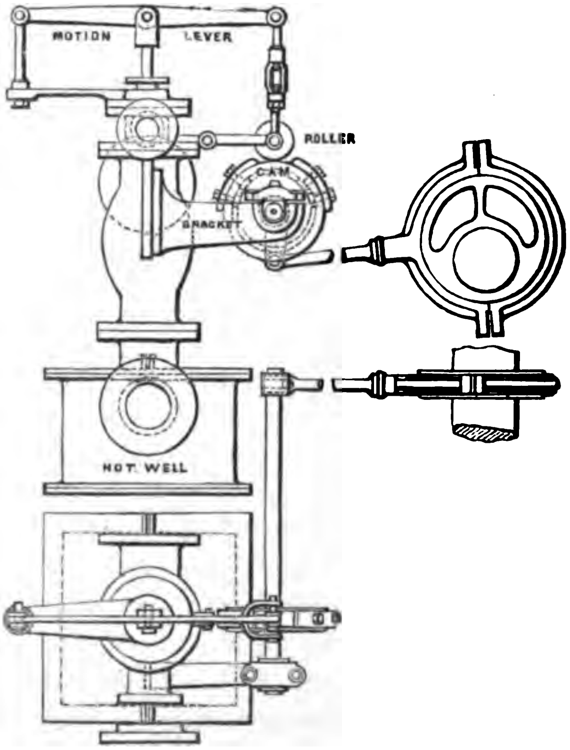
FIG. 185.



Barclay's Ejector-Condenser, fitted with a Tappet Injection Valve and Flap Discharge Valves, patented in the year 1869.

The gear for working the injection valve is shown by Fig. 186, where it is seen that the spindle is connected at the top to the centre of the lever, vibrating at one end on a joint, and having an adjustable rod joined to its opposite extremity. At the lower end of this adjustable rod is an antifriction roller, the pin carrying which passes through the end of the rod, and is supported at its ends in the arms of a forked lever vibrating on the joint fixed to a flange on the condenser. A cam, having two adjustable blocks, plates, or tappets, bolted to its periphery at a distance apart, is supported in bearings placed in the bracket bolted to a flange cast on the side of the condenser, and is placed with that part of its periphery which is not occupied by the blocks, plates, or tappets, almost touching the antifriction roller, so that when the cam, actuated by means of the crank and eccentric fixed on the engine shaft, moves, the roller is caused to rise and fall according as it comes into contact with

Fig. 186.



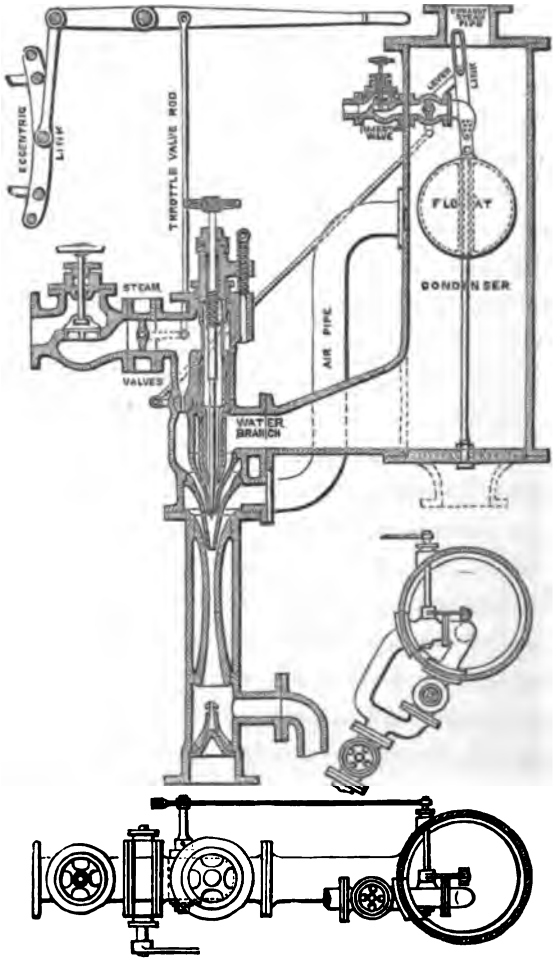
Barclay's Eccentric and Tappet Gear for Ejector-Condensers, patented in the year 1869.

or leaves the blocks, plates, or tappets, which also causes the valve spindle to rise and fall, whereby the valve is intermittently lifted, and thus allowed to fall and close on its seat. The action of this form of blow-through condenser is as follows. Directly the steam which passes into the lower part of the condenser comes into contact with the water therein it blows it out through the foot valves into the chamber or hot well, whence a sufficient quantity of it is taken to feed the boiler, whilst the remainder may be otherwise used or allowed to run to waste, and at the same time the injection valve is lifted, which allows cold water to fall into the lower part of the condenser, which instantly condenses any vapour that may remain therein, at the same time it fills the lower part of the condenser in readiness to be acted upon and blown out by the steam at the next exhaust. When the engine is in action the operations now explained are continuously repeated. It is preferred to construct the chief parts of the condenser with air spaces, or in any other way to reduce their tendency for conducting heat. For this purpose an air space, seen in the sectional view, is formed at the sides of the small water chamber in Fig. 185.

The illustration, Fig. 187, is another arrangement of gear and ejector by Mr. Barclay, showing sections of a condenser having an ejector applied thereto for withdrawing the water, uncondensed vapour, and air in lieu of an air pump.

The condenser receives the exhaust steam from a steam engine cylinder, being led thereto by the top branch. At the lower end of the condenser a branch communicates with the water nozzle of the ejector. The condenser contains a float which moves upwards and downwards in it correspondingly with the variation of the water level therein: it is guided by a central guide rod. At the upper end of the float a link is attached, having a long slot formed in it, and through which the stud in the lever passes; this lever being centred upon the spindle of the throttle valve in the injection passage, and when the level of the water in the condenser is such that the float is raised so that the lower part of the slot in the link bears upon the stud, it raises the lever into the position shown, so as to partly shut off the injection water from issuing from the perforated nozzle or rose—it being understood that the throttle valve is of such size that when in the position shown it still allows some water to pass around it.

FIG. 187.



Barclay's Ejector-Condenser, fitted with Valves and Gear, for Winding Engines, patented in the year 1869.

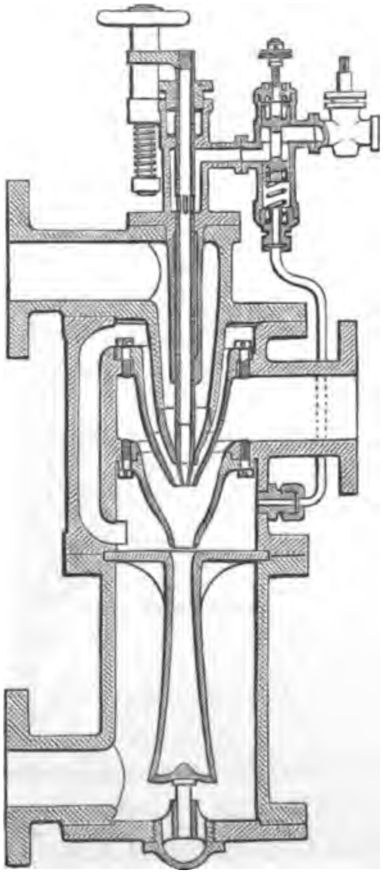
In the other case, when the level of the water in the condenser is low, the upper end of the slot in the link bears upon the stud, and therefore by the weight of the float depresses the lever, this having the effect of opening the throttle valve, so as to allow a greater amount of injection water to flow in.

The small stop valve is for admitting or shutting off the water from the injection passage, and the other or larger stop valve is for admitting or shutting off the flow of steam from the boiler into the ejector. The lever also actuates another short lever, shown in dotted lines, connected by the rod to the lever which actuates the ejector cock. The starting handle of the engine for actuating the link motion starts the engine, and at the same time adjusts the position of the throttle valve, so as to admit the desired quantity of steam into the ejector.

The lower branch of the ejector is connected by the air pipe to an opening in the condenser, by which it draws off water, air, and uncondensed vapour, when the water level is above the orifice, but it draws off air and uncondensed vapour only when the water is below the orifice.

Mr. Morton's last arrangement is illustrated by Fig. 188, which is a single steam branch ejector with double combining nozzles, and a side passage for the overflow in the first nozzle. The remaining portions of the apparatus are very much as those already explained and illustrated.

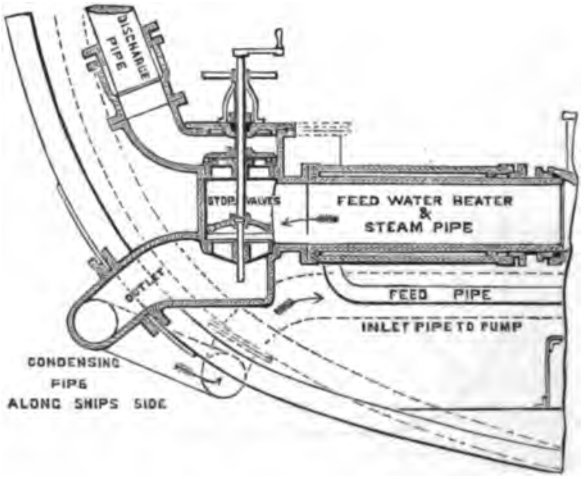
FIG. 188.



Morton's Double Combining Nozzle and Overflow Side Passage Improved Ejector-Condenser, as constructed by him for general purposes in the year 1870.

We next refer to an arrangement of self-acting condensing apparatus introduced by Mr. Crichton—in the year 1866, particularly adapted for marine engines—who has since fitted several steam royal navy launches with it with some success. A transverse section of the valves and piping are illustrated by Fig. 189, where it is seen that there are double stop valves applied to the outer end of the steam pipe, and so arranged, that when the top valve is closed and the bottom one open, the steam passes into the surface condenser or condensing pipes; and when the bottom valve is closed and the top one open, the engine can be worked as a non-condensing engine by exhausting through the exhaust discharge pipes, and by closing both the upper and lower valves in case of accident to the surface condenser, and removing the cylinder valves, the ordinary injection condenser can be brought into use. The discharge pipes extend upwards to discharge the uncondensed steam externally at a convenient part of the ship's side above the deep load line. The surface condenser pipes on each side of the vessel, which extend along the outside of the ship, are shown by Fig. 190, as passing through the screw propeller opening, and are made to return along the other side of the ship, where they terminate inboard, in connection with the stop valves.

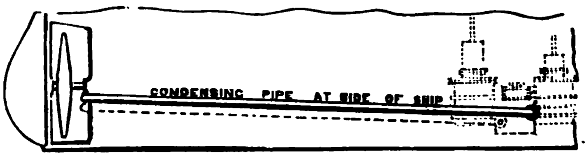
FIG. 189.


DISCHARGE PIPE
STOP VALVES
FEED WATER HEATER & STEAM PIPE
OUTLET
FEED PIPE
INLET PIPE TO PUMP
CONDENSING PIPE ALONG SHIPS SIDE

Arrangement of Crichton's Condensing Apparatus for Marine Engines, patented in the year 1866.

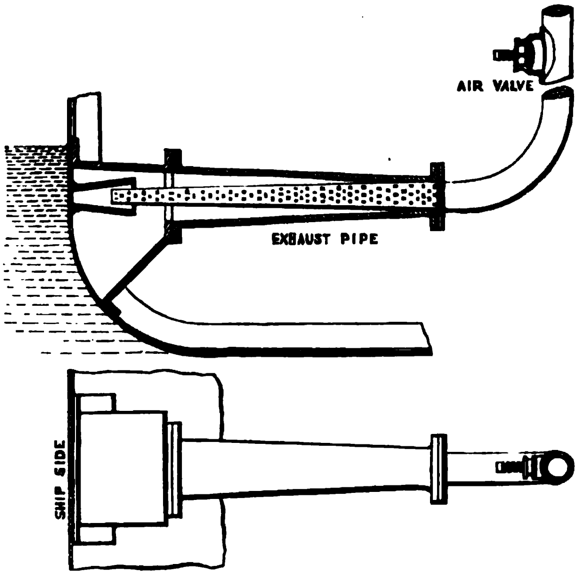
Mr. Simon's apparatus for "outside of the hull" condensation must next be noticed, as shown in sectional elevation and plan by Fig. 191, which consists of a box secured to enclose a perforated plate in the hull, at which part a small nozzle pipe is secured to discharge the water inside the box, attached to which is an exhaust pipe enclosing a perforated steam pipe in connection with a bend pipe fitted with an air valve, which opens inwards to prevent a vacuum forming in that pipe. The working of this combination of pipes is, that the water enters through the perforations in the plate and condenses the steam that issues

Fig. 190.



Crichton's Arrangement of Surface Condensing Pipes outside the hull, for the condensation of steam, patented in the year 1866.

Fig. 191.

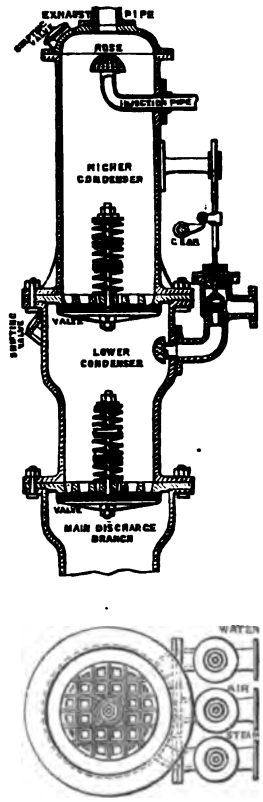


Simon's System for the Condensation of Steam outside the hull, applied in the year 1868.

from the perforated pipe; and as the vessel advances, the inside water passes through the nozzle opening, and thus a constant current of exchange of water is kept going. Of course, in this case, boiler feed water is not a relative consideration at all.

Early in the year 1870, Mr. McCarter patented the condensing apparatus illustrated by Fig. 192, which is an improvement on the example shown by Fig. 154, on page 149. The exhaust pipe from the engine communicates with the top of the higher condenser, and this has at its bottom a grated opening provided with a valve and leading into the lower condenser, whilst the latter has at its bottom a grated opening provided with a valve and leading into the discharge branch. The valves are metal discs covered with vulcanised rubber on their upper sides, to close up against the under sides of the grated openings, and the discs have fixed to them spindles, which pass up through the centres of the gratings, and have spiral springs applied to them in such a way as to tend to lift the valves up to the gratings. These springs rest upon the gratings, and their upper ends press up against washers fixed on the upper ends of the spindles by screw nuts, and by means of the screw nuts the action of the springs is nicely adjusted. Both compartments are fitted with rose nozzles for the injection of cold water, but whilst one in the upper compartment is always open, the other in the lower one is generally closed by a valve. The lower compartment is provided with two other valved inlets, as best seen in the plan, one being for air and the other for steam. The three valves are by preference equilibrium valves, and are opened at proper times by cams,

Fig. 192.



McCarter's Improved Condensing Apparatus, patented in the year 1870.

such as the one shown on a horizontal shaft, which is made to revolve by gearing from the main shaft of the steam engine. Both compartments are fitted with snifting valves, for the escape of air, these valves being simple hinged lids which open outwards whenever the internal pressure is greater than that of the atmosphere. The upper compartment acts like an ordinary injection condenser, and the water due to the condensation of the steam from the engine accumulates in it along with the injection water until its weight is sufficient to overcome the spring and open the upper valve, which it does when there is a vacuum in the lower compartment. The water, which on the opening of the valve passes to the lower compartment, is got rid of from the latter by opening the air valve, whereupon the atmospheric pressure on the under side of the lower valve being thus counterbalanced, the water opens that valve by its weight and passes into the waste pipe, the valve of course closing again by the action of its spring. The air valve is then closed and the steam valve opened, the steam blowing the air out of the compartment by the snifting valve and filling the compartment.

We have thus far dealt with the condensation of steam by the agency of water; but we now direct attention to the use of "air" as the means, *i.e.*, cold air in the place of cold water. We had some experience with "air condensers" in the year 1860, in which the steam was admitted through narrow long openings, so as to be in contact with a current or volume of air sufficient to carry away the steam and condense it within the required distance for the purpose, but the result attained was far from being economical, and thus it died a financial death.

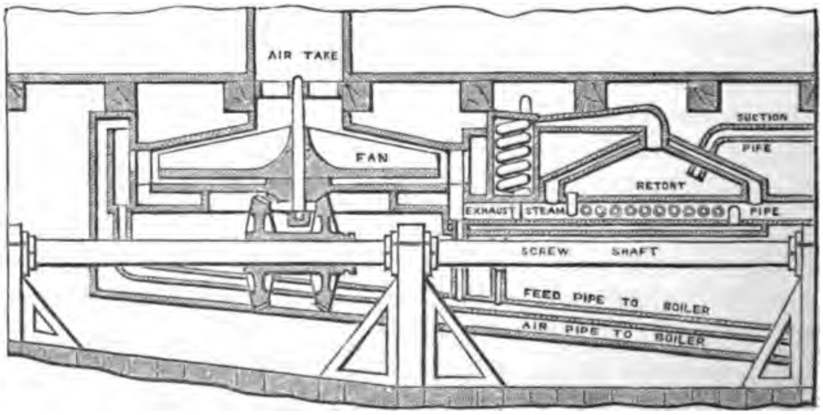
In the year 1864 a Mr. Thorold patented an arrangement of an air condenser, and the necessary apparatus for working the same in connection with marine steam engines, which we illustrate as an impossibility, by Fig. 193.

The exhaust steam from the steam engines passes to the circular passage, from thence through the current divider into the condensing chamber, wherein is a fan of large diameter, drawing in air through the air take, driven from the screw shaft by means of frictional gearing, of which the vertical wheels slide upon the screw shaft, so as to be put in gear with opposite sides of the fan wheel, for the purpose of driving the fan always in the same direction, in whatever direction the screw shaft may revolve.

The passage into which the uncondensed gases pass is in connection with the air pipe for conducting the same to the furnaces of the boilers; the boiler feed water being conveyed by a separate pipe above the air pipe.

As a certain small quantity of water will always pass away as uncondensed gases, it will be requisite to make good such loss by evaporating a corresponding quantity of fresh water from the sea water. For this purpose a conical retort is placed over the exhaust steam pipe, and a flat vessel is placed below the same, and sea water is introduced first into the latter through the worm, and is then caused to pass through the coil of pipes situated in the steam pipe and into the retort. This retort is furthermore surrounded by passages filled with the exhaust steam, and the sea water becoming thus heated by close contact with the different steam-heated surfaces, the evaporation of fresh water to the required extent takes place.

Fig. 193.



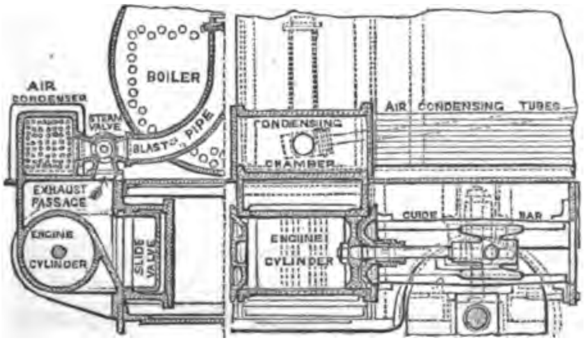
Thorold's Air Condenser, for the condensation of steam from Marine Engines, patented in the year 1864.

CHAPTER XVI.

CONDENSING APPARATUS FOR LOCOMOTIVE ENGINES.

When the Metropolitan Underground Railway scheme was discussed in scientific circles about ten years ago, the question arose as to what should or could be done with the steam from the engine and the smoke and gases from the chimneys; for it was very evident that no practical system of tunnel ventilation could be carried out sufficiently to dispose of those existing barriers entirely. The smoke was got rid of by burning smokeless coal, and the gases by tunnel ventilation, while the steam was condensed, which latter process forms our next subject.

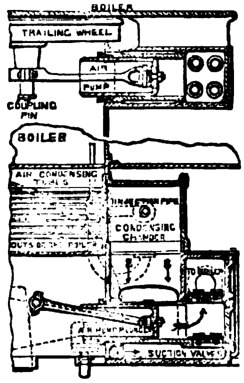
Fig. 194.



Slaughter's Air Surface Condenser and Water Injection Condenser, for Locomotive Engines, patented in the year 1863.

Foremost amongst patentees at that time came Mr. Slaughter of Bristol renown, with his scheme as illustrated by Fig. 194, the arrangement being that the exhaust steam, when the engine is running in the open air, passes away through blast pipes as usual, but when the locomotive engine is passing into or through a tunnel or underground railway, the steam is shut off from the blast pipes, and caused to pass through the surface condenser in the following manner. On the passages leading from the steam cylinders into the chimney, a cock or valve is applied, and also a branch pipe or junction leading into a chamber at one end of the surface condenser. When the three-way cock or valve is so turned by means of the handle as to shut off the exhaust from the blast pipes, the exhaust steam passes away from the cylinders through the cock into the surface condenser, where the exhaust steam is partially condensed; it thence passes into an injection condenser of the ordinary description, where it is condensed by a jet of cold water supplied in the following manner. There is a tank divided horizontally into two parts, having an air space between them, in order that the temperature of the water in one compartment may not be communicated to that in the other. This tank is supported on an extra pair of wheels, and the two compartments referred to are each capable of holding the necessary quantity of water for service between the terminal stations of an underground railway. On commencing to work, the cold water is run into the cold water tank, and is used for injection into the condenser by passing through the suction pipe, cock, and injection pipe, which is perforated with numerous holes. The condensed steam and injection water, together with any air or gases therewith collected, are then pumped by the air pump into that part of the tank for holding hot water. The air pump is worked from the crank pin of the trailing coupled wheels, as shown by Fig. 195. The suction and discharge valves are under and over the pump, and the water and gases are discharged into the hot water tank from which the boiler is supplied.

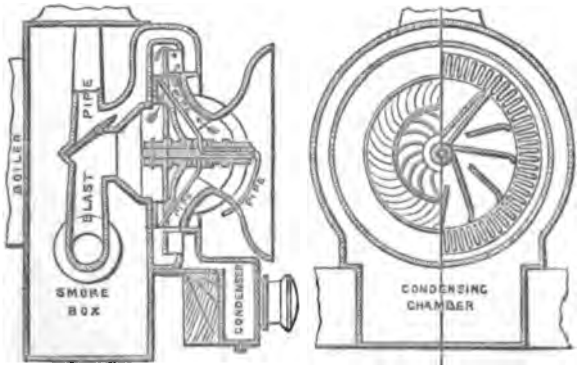
Fig. 195.



Slaughter's Air Pump, Water Injection, and portiou of Air Surface Condensers, for Locomotive Engines, patented in the year 1863.

The surface condenser is composed, as shown, of a number of small tubes, or it may be narrow passages. These small tubes do not extend from end to end of the surface condenser, but for convenience of manufacture and otherwise are divided into two sets connected together by a short chamber. The steam is partially condensed in passing through the condenser by the atmosphere acting upon the outer surfaces of the tubes of which it is composed, or these tubes or some of them may be immersed in a tank of cold water. In some cases the surface condenser may be dispensed with. The steam would then, when shut off from the blast pipe, be caused to pass directly to the injection condenser. The ash pan is also arranged, as has heretofore been done, so as to be closed when the exhaust steam is shut off from the blast pipes.

FIG. 196.



Thorold's Water and Air Condensing Apparatus, for the Condensation of Steam in Locomotives, patented in the year 1864.

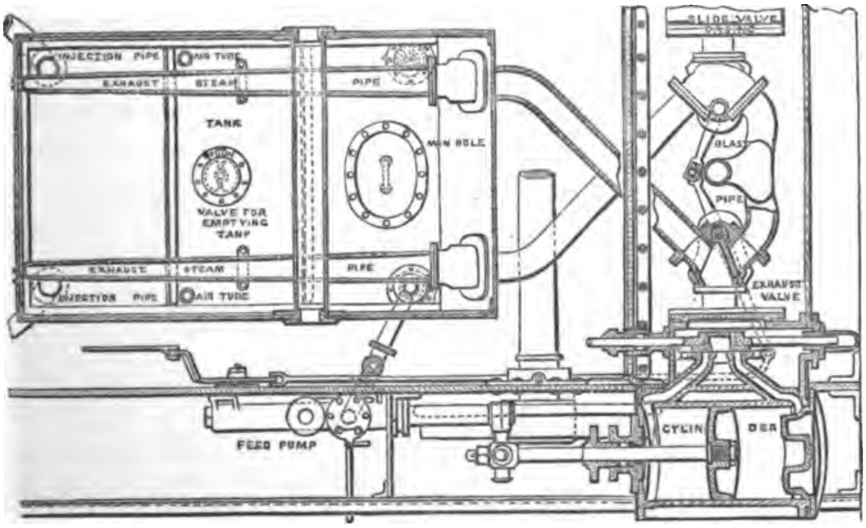
Very soon after Mr. Slaughter there came Mr. Thorold, with a host of arrangements for the condensation of steam from locomotive engines. Centrifugal fans were his pets in the scheme, driven by belts on the leading wheels of the locomotives generally; but exceptionally by the resistance of the air on the fans when the locomotive was running, as illustrated in side and front sectional elevations by Fig. 196. The arrangement of the apparatus is this:—

The blast pipe is provided with a throttle valve, which, when placed in the position shown, causes the exhaust steam to pass into the fixed guide vanes to the turbine running loose upon the fixed spindle. The steam reacting upon the vanes of the turbine causes the same to revolve rapidly, and issues from the periphery of the same into the surrounding enclosed passage. Upon the back of the turbine are fixed the fan blades, which, in rotating rapidly with the turbine, draw the external air in through the eye of the casing, and throw it out at the periphery. The velocity with which the air enters the fan is greatly increased by the speed with which the locomotive drives the fan against it; and in order to increase the pressure to the utmost, a wind bell-mouthed collector is fixed to the eye of the fan casing, so as to collect and conduct the greatest possible quantity of air into the fan. The steam issuing from the turbine into the passage, and the air thrown from the circumference of the fan, instead of being brought immediately in contact with each other, are first caused to pass through alternate narrow passages in the current divider, as indicated by the arrows, from which they issue in alternate small streams into the condensing chamber. The steam is thus brought into most intimate contact with the air, and is thereby condensed. The construction of the current divider consists of a plate of thin metal bent into a zig-zag form, as shown, so as to form a number of narrow spaces, closed by a plate at the back in such a manner that the steam can only enter the chamber through the spaces, whilst the air can only pass in through the spaces, as shown by the arrows. Water in the form of spray is introduced into the passage, to assist in the condensation of the steam, through pipes rotating with the turbine and fan, which pipes are supplied with water from the gland box communicating with the supply pipe, through the passage formed in the spindle. The gland box is kept water tight upon the spindle by means of leather collars placed on either side, as shown. The water resulting from the condensation of the steam, as above described, passes down through the chamber into the condenser, whence it is conveyed through the bottom pipe into the boiler by means of a pump or injector. The uncondensed gases pass from the chamber through the passage into the blast pipe, so as to compensate to some extent for the abstraction of the steam blast.

The possibility of this arrangement seems as doubtful as the inventor's most powerful enemy—if he has one—could wish, but we illustrate it as a companion to Fig. 193 on page 192.

We now turn to a *bonâ fide* arrangement that has been practically used with success on the Underground Metropolitan Railway. The plan of the engine, condensing tank, valves, and gear, are shown by Fig. 197. Each cylinder is secured outside the smoke-box, nearly over the leading wheel: the right hand cylinder is shown only in this view, together with the slide valve and casing. The condensing tank is shown in section also, and contains the two exhaust steam pipes, emptying valve, man hole, feed water strainer, and starting shaft tubing. The supply water tank is between the trailing wheels under the foot plate, as illustrated by Fig. 198 in sectional plan, with the pipes and connections. The injection pipes in each view are

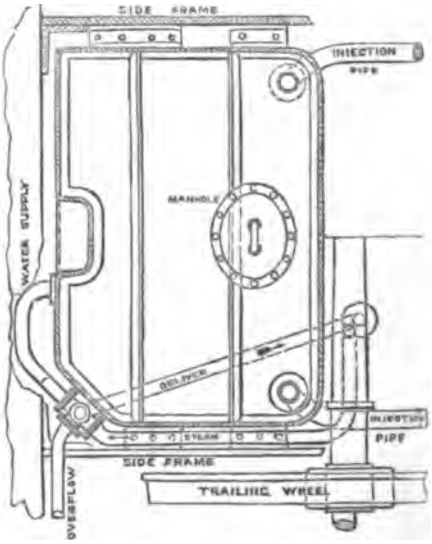
FIG. 197.



Sectional Plan of a portion of the Condensing Locomotive running on the Metropolitan Underground Railway in the year 1866.

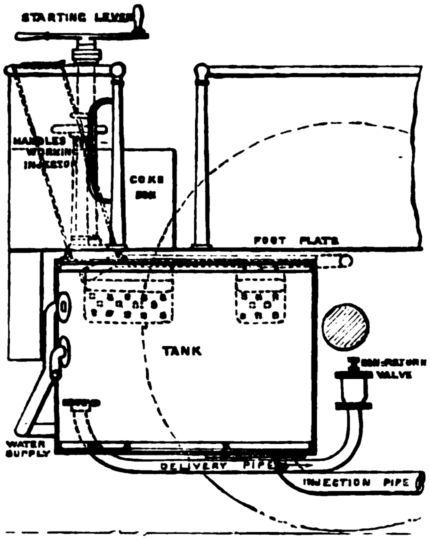
practically the connecting pipes of the tanks. The side sectional elevation of the supply tank is shown by Fig. 199, with the foot plate, hand railing, and general fittings.

Fig 198.



Sectional Plan of the Supply Water Tank for the Condensing Tank shown by Fig. 197.

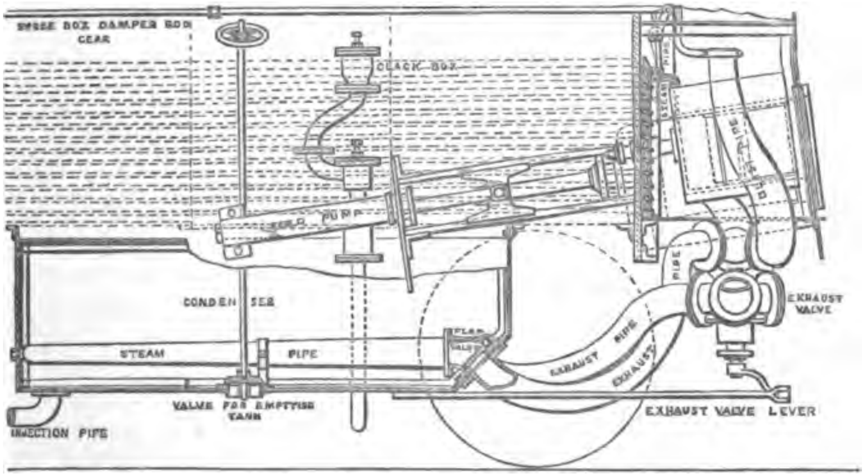
Fig. 199.



Side Sectional Elevation of the Supply Water Tank for the Condensing Tank shown by Fig. 197.

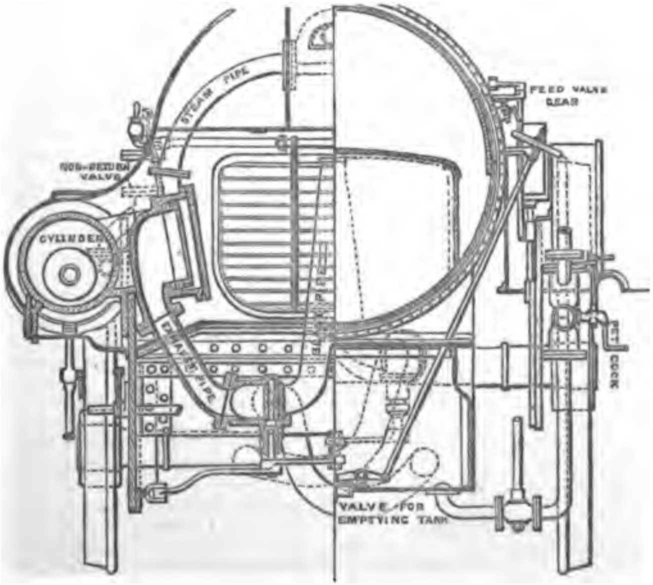
The sectional side elevation of the plan shown by Fig. 197 is illustrated by Fig. 200, which represents the various details in a corresponding position; as also does the end sectional elevation, shown by Fig. 201.

FIG. 200.



Side Sectional Elevation of the Condensing Locomotive running on the Metropolitan Underground Railway in the year 1866.

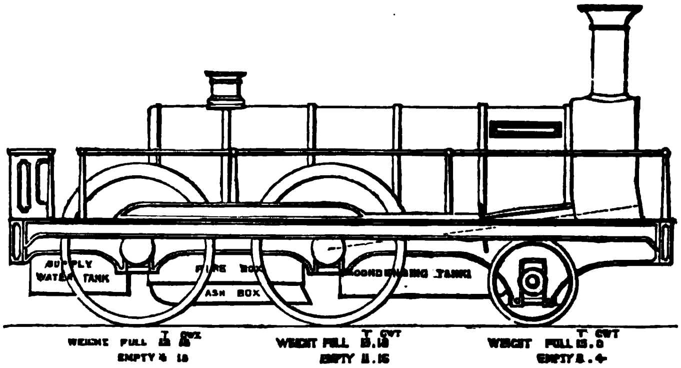
FIG. 201.



Front and Sectional Elevation of the Condensing Locomotive running on the Metropolitan Underground Railway in the year 1866.

The arrangement of the two tanks under the boiler is shown by Fig. 202, which is a side elevation of the locomotive, giving also the weights at the six points of adhesion.

FIG. 202.



Weights on the Points of Adhesion, and Arrangement of the Condensing and Supply Water Tanks, in the Condensing Locomotive running on the Metropolitan Underground Railway in the year 1866.

	ft.	in.
Diameter of Cylinders	0	16
Length of Stroke	2	0
Width of Supply Ports in Cylinder	0	1½
Width of Exhaust Port in Cylinder	0	2¾
Width of Exhaust Port in Valve	0	3⅝
Outside Lap of Valve	0	1½
Width of Valve	0	10¼
Length of Ports	0	13
Length of Valve	0	15½
Thickness of Bars in Cylinder	0	0¾
Travel of Valve	0	5¾
Thickness of Metal in Cylinder	0	1
From Centre of Cylinder to Centre of Valve Spindle	1	7¾
Diameter of Piston Rod	0	2½
From Centre of Cylinders to Centre of Boiler	4	1
Diameter of Feed Pumps	0	3
Diameter of Steam Pipe (inside)	0	3
Diameter of Exhaust Pipe	0	4
Length of Connecting Rod between Centres	7	6
Diameter of Driving Wheel	6	0
Diameter of Coupled Wheel	6	0
Diameter of Leading Wheel	3	6
From Centre of Driving Wheel to Centre of Leading Wheel	8	0
From Centre of Driving Wheel to Centre of Coupled Wheel	7	6

BOILER.

	ft.	in.
Diameter of Boiler (inside)	4	9
Thickness of Plates	0	$0\frac{7}{16}$
Length of Fire-box shell (outside)	6	0
Width of ditto ditto	4	9⅞
Height of Fire-box shell (outside)	7	4⅝
Length of Fire-box at Bottom	4	$11\frac{15}{16}$
Ditto ditto Top	4	9⅛
End Water Space at Top	0	7
Ditto ditto Bottom	0	6
Back Water Space at Top	0	6½
Ditto ditto Bottom	0	6
Centre Water Space at Top	0	6½
Ditto ditto Bottom	0	6
Copper Stay for Fire-box, diameter	0	1
Pitch, 4 × 4 inches.		
Width of Fire-box	3	10½
Height of Fire-box	4	5½
Number of Tubes, 122.		
Diameter of Tubes, outside	0	2
Ditto ditto inside	0	1¾
Thickness of Tube Plate	0	0⅝
Length of Tubes	11	2
Length of Barrel	10	6
Longitudinal Stays, diameter	0	1⅛
Pitch of Rivets	0	1⅞
Length of Smoke-box at Top	2	6⅜
Ditto ditto Bottom	2	11½
Thickness of Plates at Back of Smoke-box	0	$0\frac{5}{16}$
Height of Steam Pipe above Centre Line of Boiler	1	10
Boiler Feed Cock	0	2¼
Diameter of Chimney on Top, inside	1	3½
Ditto ditto Bottom	1	4
Thickness of Plates	0	$0\frac{3}{16}$
Height from Top of Smoke-box	3	7
From Rail Level to Centre of Boiler	6	0
Ditto Top of Outside Fire-box	8	$4\frac{15}{16}$
Ditto Underneath Shell of Fire-box	1	0
Ditto Frame Level	4	1

CONDENSER TANK.

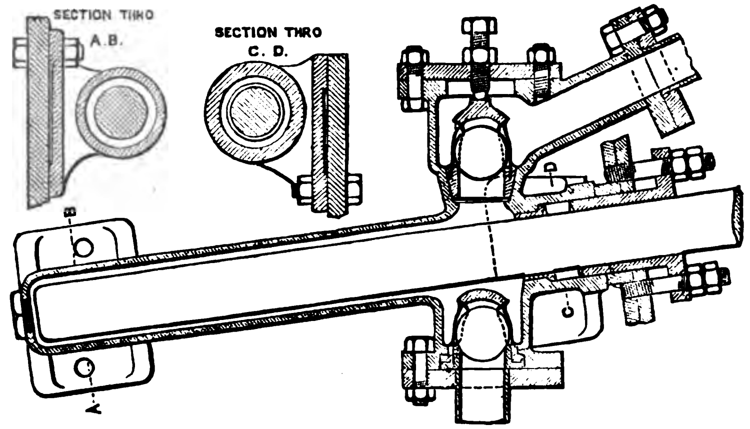
	ft.	in.
Length of Tank	7	2
Width of ditto	4	3
Depth of ditto	2	3
Man-hole in the Bottom of Tank, 12 × 15.		
Valve for Emptying Tank, diameter	0	6
Exhaust Steam Pipe, 5 ins. large end, 3 ins. small end.		
Water Supply to Condenser, inside	0	3
Thickness of Plates at ends	0	0$\frac{5}{16}$
Thickness of Plates at Sides	0	0⅛
Thickness of Plates at Bottom	0	0$\frac{3}{16}$
Angle Iron	0	1½
Air Pipe at Top, inside diameter	0	2¼

COLD WATER SUPPLY TANK.

	ft.	in.
Length of Tank	3	11
Width of ditto	5	5
Depth of ditto	2	10
Thickness of Plates at Sides	0	0¼
Ditto ditto Ends	0	0⅛
Ditto ditto Top	0	0⅛
Ditto ditto Bottom	0	0$\frac{3}{16}$

We next direct attention to the details, beginning with the feed pump, which is illustrated by Fig. 203: being the ball valve arrangement. The suction valve seating is formed with the flange of the pipe, and the guard surrounds the projection, the jointing securing the two details in position. The discharge valve and seating directly above is different in connection; as in this case the seating is a cone tube, around which the guard is screwed on the larger part; and on the top of the guard is a set stud which keeps that and the seating down in their proper position. As the various details and sections are fully explained by themselves, we shall turn next to the exhaust steam valve, which directs the steam into the chimney or tank, illustrated by Fig. 204. The valve is flat, square shaped, and hung at the back on a square spindle. The casing is of a peculiar form, having

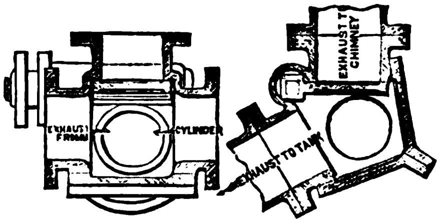
FIG. 203.



Feed and Air Pump fitted to the Condensing Locomotive running on the Metropolitan Underground Railway in the year 1866.

also two doors to remove or inspect the valve, without breaking the other joint connections.

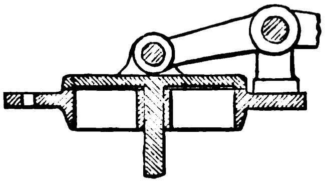
FIG. 204.



Exhaust Steam Valve, to direct the Steam either to the Chimney or to the Condensing Tank of the Condensing Locomotive shown in connection in Fig. 197.

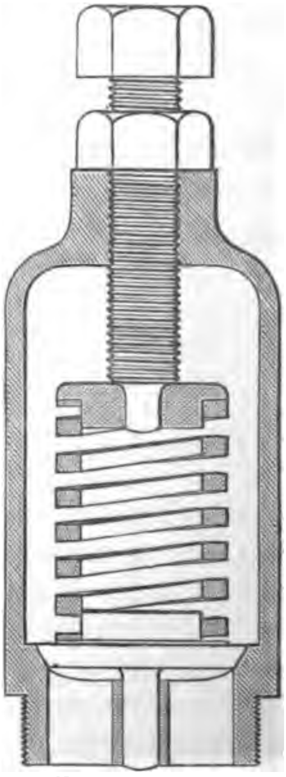
The next detail worthy of notice is the valve for emptying the tank, as illustrated by Fig. 205. This is simply a disc spindle valve, raised and lowered by a lever over it.

FIG. 205.



Valve for emptying the Condensing Tank of the Locomotive shown by Fig. 197.

FIG. 206.

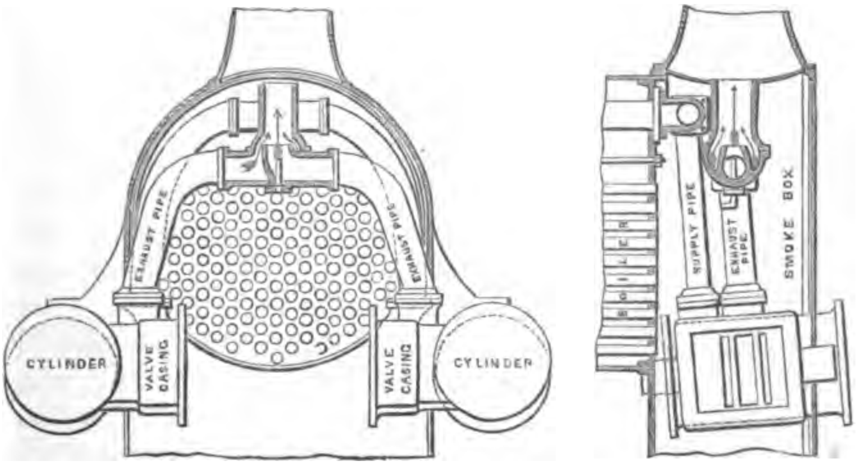


Relief Valve and Casing for the Pump illustrated by Fig 203.

The feed pump being an important detail in this matter, as it is an air pump also, we illustrate the relief valve by Fig. 206, which shows also the spring, set screw, and casing, in sectional elevation. The discharge opening is on the half of the casing not shown.

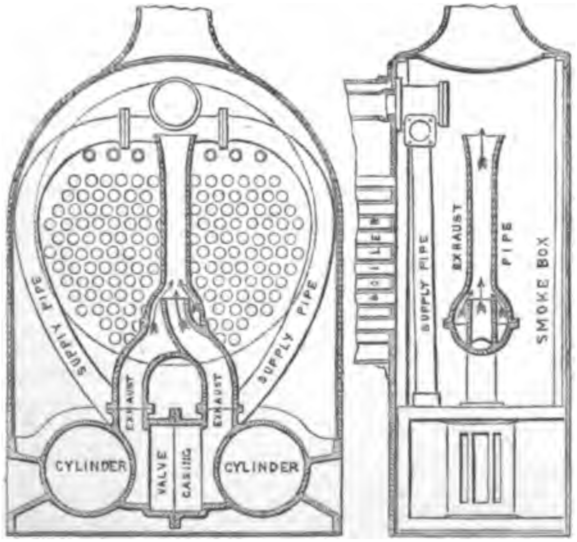
A very novel and ingenious method for causing a *partial* vacuum with high pressure non-condensing engines was patented by Mr. Morton in the year 1867, at the same time that he patented his ejectors already noticed in the previous chapter. The illustration, Fig. 207, represents sectional views of this apparatus applied to an outside cylinder locomotive, and Fig. 208 a simpler method on the same principle to an inside cylinder locomotive. In each of the two arrangements

FIG. 207.



Morton's arrangement of Central and Annular Nozzles, to cause a *partial* vacuum in Outside Cylinder Locomotive Engines, patented in the year 1867.

FIG. 208.



Morton's arrangement of Central and Annular Nozzles, to cause a partial vacuum in Inside Cylinder Locomotive Engines, patented in the year 1867.

shown, the exhaust pipe from one cylinder, and the exhaust pipe from the other cylinder, both alternately discharge the exhaust or waste steam from their respective cylinders through the induction tube or pipe which is common to both. The exhaust steam on leaving the right hand takes the form of a central jet, whilst that from the other pipe takes the form of an annular jet round the central one, the areas of both orifices being nearly equal and somewhat less than the least area of the induction tube at the throat. The lateral action of the exhaust steam from the central jet or orifice, in passing through the induction tube, induces a partial vacuum in the left-hand pipe, and that from the annular jet produces an equal vacuum in the right-hand pipe respectively, and alternately as the exhaust steam is allowed to escape from the respective cylinders; and this alternate drawing action, or any increase either in the pressure of the exhaust steam or in the velocity of the engine, produces a corresponding or an increased vacuum on the back of the steam piston alternately and respectively, instead of a back pressure as heretofore. Although the central jet is shown as cylindrical, it is to be understood that it or both jets, or other number of these jets when more are used, may be made annular when desired by the use of a central cylindrical or annular metal spindle, either fixed or adjustable, or the central one may be made annular by the use of the usual blast pipe placed as shown in Fig. 207, furnished with a cock for the purpose of inducing a draught or current in the fire-box, and through the tubes and chimney by a jet of steam direct from the boiler when the engines are not at work, or to increase the vacuum or draught, as described at other times, when desired.

CHAPTER XVII.

THE PRINCIPLES OF CONDENSATION OF STEAM PRACTICALLY CONSIDERED.

STEAM.—The constituent parts of steam are, Water, Heat, and Air. The Water is the amount put into the boiler as feed water. The Heat is the product of combustion that has penetrated the fire plates and tubes in contact with the fluid; and the Air is the constituent in the water when it entered the boiler, so its proportion is constant, whereas the water is reduced as the heat is increased, from the fact that the caloric absorbs the fluid and carries it away in the form of a saturated gas, the amount of saturation being in proportion to the temperature.

FORMATION OF STEAM.—We have first to notice now the fact why air is supposed to be in the feed water, which is, that water is acknowledged to be composed of invisible solid spheres of the same material, and the spaces between them are filled with air, which a very domestic experiment is said to prove, by putting salt or sugar into a *full* glass of water, which does not run over until an extreme quantity has been absorbed. We mention this because it is a familiar proof, but withal does *not* prove that there are spheres and that they are solid; in fact, we are more inclined to believe that water is composed of solid layers at great depths, and passing higher into spheroids with a minute amount of air in them, and from that into spheres of a thinner kind filled with air also. And our reason for that belief is, that as water was originally air, it always contains some of that element while in a liquid state, and therefore loses it only when solid, such as ice, and even then perhaps some remains. Or if a better explanation be required, how could steam be formed if there were no gaseous ingredients in the water?

Next as to the actual beginning of steam-making in a boiler. Suppose a boiler, say a marine one, has the proper amount of cold water in it, and the fires are lighted: immediately the heat begins to act on the fire-side of the plates and tubes and penetrates to the water-side, the fluid feels the effect. Then as the water recoils from the heated surface it forms with the heat into atoms of minute size, and as the heat is lighter than the water, it ascends through the volume above and warms it also, so that on arriving at the surface it is reduced in temperature.

From a continuance of heat the fluid has an affinity to that circumstance, and thus a more rapid circulation occurs; until the displacements of the atoms of water are so quick as to cause an ebullition on the surface of the fluid.

The *rise* of steam vapour then occurs,* and the heat forms the atoms of water into more minute and finer globes,—which on rising leave vacancies as before, that are filled with those surrounding, because if not a cessation results—and those globes, being filled with air and heat covered with a skin of water, are buoyant, and thus ascend to the water line and form steam.

---

* *Opinion of Robert J. Lecky, Esq., of the Firm of Messrs. Whieldon, Lecky, and Co.*—"You ask me for my ideas relating to vapour. They are very simple; merely, that all vapour, from the delicate gossamer fog you see of a summer's evening hovering over a dewy meadow, to a Scotch mist on the side of Ben Lomond, is composed of spheres of *solid* water suspended in the air, only varying in size. As the proportion between weight and surface is (in a decreasing ratio) that of the inverse of the cubes to the squares, you can easily see how extremely light in proportion to surface these infinitesimal drops of water must be; and therefore the friction must be very much greater in proportion than the weight, thus keeping them so much longer afloat in the atmosphere, sufficiently long to admit of their evaporating, and becoming again absorbed by the air as its temperature increases, and so disappearing. I can in no way agree with the old idea, that these drops are hollow spheres filled with air. How could the air get there? Simply impossible, and I see no need for such a theory when we can so easily account for vapour floating, as I said before. The floating of clouds is more or less affected by electricity, but this is foreign to your query, so I need not go into it; and steam, as seen escaping from a tea-kettle or a gauge-cock, is but vapour as distinguished from steam proper, which, as we all know, is perfectly transparent, and except for what air may be in solution in the water beforehand, is, in my view, perfectly free from air.

We know from those circumstances that the method of steam-making is the same always, *i.e.*, independent of pressure, but that the higher the temperature the more rapid is the production.

The spheroidal shape of the atoms of water that we have alluded to will apply also to the conversion of steam under a pressure of the same, because the weight of the steam will produce that effect; inasmuch that although there may be pressure contained in a boiler, it is nearly equal at all parts as far as steam force is concerned, but not as to weight, and that a discharge opening at the lowest corner of the boiler will be more effectual than at the side or centre of the bottom.

Knowing then that there is weight to be considered in the formation of steam, we may safely conclude that the higher the temperature and pressure the more weight there is in operation, and that steam in any form is but so many pounds of heat, water, and air in a gaseous condition, in proportion to the temperature. We therefore ignore the common belief that increase of pressure is entirely dependent on heat, but rather that it is dependent on water also, as for example: suppose a boiler has its feed water cut off, but the fires continued, with no escape of steam; the result is that the pressure increases during the evaporation of the water or its conversion into steam, but directly that ceases the rise of the pressure gradually stops also, and although heat may be put in the gas it will not increase the pressure to any extent as before; while the result is that the temperature becomes so high that the metal expands, and an escape or bursting ensues, which is erroneously credited to the continued increase of pressure rather than the separation of the fibres of the metal.

Referring next to the weight of steam at various pressures, the weights of its constituents must be considered separately and then added together. Or, as Professor Rankine, M. Regnault, Dalton, &c., state: "Pressure exerted against the interior of a vessel by a given quantity of a perfect gas enclosed in it, is the sum of the pressures which any number of parts into which such quantity might be divided would exert separately, if each were enclosed in a vessel of the same bulk alone, at the same temperature; and that, although this law is not exactly true for any actual gas, it is very nearly true for many. Thus, if 0·080728 lb. of air, at 32°, being enclosed in a vessel of one cubic foot of capacity, exerts a pressure of one atmosphere, or 14·7 lbs., on each square inch of the interior of the vessel, then will each additional 0·080728 lb. of air which is enclosed, at 32°, in the same vessel, produce very nearly an additional atmosphere of pressure. It has now further to be explained, that *the same law is applicable to mixtures of gases of different kinds.* For example, 0·12344 lb. of carbonic acid gas, at 32°, being enclosed in a vessel of one cubic foot in capacity, exerts a pressure of one atmosphere; consequently, if 0·080728 lb. of air and 0·12344 lb. of carbonic acid, mixed, be enclosed at the temperature of 32° in a vessel of one cubic foot of capacity, the mixture will exert a pressure of two atmospheres. As a second example: let 0·080728 lb. of air, at 212°, be enclosed in a vessel of one cubic foot, it will exert a pressure of

$$\frac{212^\circ+461^\circ\cdot 2}{32^\circ+461^\circ\cdot 2}=1\cdot 365 \text{ atmosphere.}$$

"Let 0·03797 lb. of steam, at 212°, be enclosed in a vessel of one cubic foot: it will exert a pressure of one atmosphere. Consequently, if 0·080728 lb. of air and 0·03797 lb. of steam be mixed and enclosed together, at 212°, in a vessel of one cubic foot, the mixture will exert a pressure of 2·365 atmospheres. It is a common but erroneous practice, in elementary books on physics, to describe this law as constituting a *difference* between mixed and homogeneous gases; whereas it is obvious, that for mixed and homogeneous gases the law of pressure is exactly the same,—viz., that *the pressure of the whole of a gaseous mass is the sum of the pressures of all its parts.* This is one of the laws of mixtures of gases and vapours. A *second* law is, that *the presence of a foreign gaseous substance in contact with the surface of a solid or liquid, does not affect the density of the vapour of* *that solid or liquid*, unless (as M. Regnault has recently shown) there is a tendency to chemical combination between the two substances, in which case the density of the vapour is slightly increased. For example: let there be a mass of liquid water in a receiver, at the temperature of 212°, and above the surface of the liquid water let there be a space of one cubic foot; it is necessary to molecular equilibrium at the given temperature of 212°, that that space of one cubic foot should contain 0·03797 lb. of steam, whether the space be void of all substances, or filled with any quantity of air, or of any other gaseous substance which does not exert an appreciable chemical attraction on the water. To illustrate the law further, let the temperature of the water be 50°: then it is necessary to molecular equilibrium that the space of one cubic foot above the water should contain 0·00058 lb. of watery vapour, whether and to what amount soever air, or any other gaseous substance not chemically attracting the water, is contained in the same space. This and the preceding law of mixtures of gases and vapours (discovered by Dalton and Gay-Lussac) enable the following question to be solved:—*Problem.* Given the total pressure P, of a mixture of a gas and of a given vapour, in a space saturated with the vapour at the temperature T: required the pressure and density of the gas separately.—*Solution.* Find, from a table of experiments, or from a formula, the pressure of saturation of the vapour for the given temperature T; let it be denoted by p; then the pressure of the gas is $P - p$; and its density is less than the density which it would have had under the pressure P, if no vapour had been present, in the ratio

$$\frac{P - p}{P}.$$

Example. A space contains mixed air and steam, being saturated with steam at 50°, and the total pressure is 14·7 lbs. on the square inch; what is the pressure of the air separately, and what weight of air is contained in each cubic foot of the space? —*Answer.* Either from M. Regnault's experiments, or from the formula already cited, it appears that the pressure of the steam is 0·173 lb. per square inch; consequently, the pressure of the air separately is $14{\cdot}7 - 0{\cdot}173 = 14{\cdot}527$ lb. per square inch. Also, the weight of air in a cubic foot, at 14·7 lb. per square inch and 50°, had there been no steam present, would have been

$$0{\cdot}080728 \times \frac{493^\circ{\cdot}2}{50^\circ + 461^\circ{\cdot}2} = 0{\cdot}077885 \text{ lb.};$$

consequently the weight of air actually present along with the steam, in a cubic foot, is

$$0{\cdot}077885 \times \frac{14{\cdot}527}{14{\cdot}7} = 0{\cdot}07698 \text{ lb.}$$

A second problem is, to find the density of the mixture of gas and vapour: which is solved by adding to the density of the gas already found, the density of the vapour as computed by the methods formerly referred to. Thus, in the case last given, it appears, by computing from the latent heat of evaporation, that the weight of steam in a cubic foot is 0·00058 lb.; consequently, the weight of a cubic foot of the mixture of air and steam is $0{\cdot}07698 + 0{\cdot}00058 = 0{\cdot}07756$ lb."

Besides the ingredients mentioned, steam will contain—when sea water in its natural state is used as feed-water—a certain amount of solid matter, which, although considerably heavier than gas, will by impetus amalgamate with the steam to a small extent, and the remainder form incrustation in the boiler. Those solidities are:—

Total quantity	1000
Water	964·745
Chloride of sodium	27·059
Chloride of potassium . . .	0·766
Chloride of magnesium . .	3·666
Bromide of magnesium . .	0·029
Sulphate of magnesia . . .	2·296
Sulphate of lime	1·406
Carbonate of lime	0·033

It will be apparent, therefore, that when injection condensers are used in steam-ships, the steam is impregnated with solid matter, which doubtless holds the heat proportionately as much as the water contained in the steam or the saturation thereof. While with surface condensers, the feed-water being nearly all distilled, the solid portions are exterminated after the first supply. These conclusions, although extreme, are nevertheless truthful, and are introduced as facts to be taken into consideration when the real nature and properties of steam must be understood.

Having explained what steam is composed of, we will next describe its progress from the boiler to the condenser. When leaving the boiler to pass to the slide-valve casing, its progress is slightly checked by the bends of the pipes, and on entering the casing a greater check occurs, owing to the alteration of the form of the opening, or port, it enters through into the cylinder; and here the supply is kept up until the valve shuts it off, when expansion commences, with the reduction of pressure and heat, to the end, or nearly, of the stroke of the piston, and from thence to the condenser; or, if a compound engine, into the larger cylinder, when a further falling of the pressure and heat ensues before the condenser receives it. The utility of these conclusions is to know what heat is in the steam when it is ready for condensation, and thus enables the proper amount of injection water or tube-cooling surface to be determined.

We proceed to the principles of the condenser, both the injection and the surface kinds, next.

THE PRINCIPLES OF INJECTION CONDENSERS.—Those principles refer to the position of the steam opening in relation to the injection rose-pipe, which positions as a rule, with very few exceptions, are wrongly situated, because it is often the practice to allow the steam to enter at the top of the condenser and the water to *meet* it below, whereas the correct positions are for the injection valve and rose or plate to be on the top of the condenser, and the steam to enter below, which is thus met by a shower of water that, assisted by its weight, causes a better vacuum than by any other arrangement. This is illustrated by Figs. 14 and 23, on pages 16 and 26, where it will be seen that the condensers are over the pumps also, which is another advantage over the usual arrangement, where the condenser and pumps are on the same level, and the water has to *rise* instead of *fall* into the barrel. We were, we believe, the first to arrange both land and marine condensers and pumps according to those principles, and the marine arrangement is shown by Figs. 41, 42, and 43, on pages 45, 46, and 47, respectively. By these mechanical arrangements a better vacuum is always obtained, from the fact that the steam is immediately destroyed, and then assisted by its liquid gravity to leave the condenser, exceptionally to the action of the air pump.

THE PRINCIPLES OF SURFACE CONDENSERS.—When Mr. J. F. Spencer read his paper on "Surface Condensers," at the Institution of Engineers in Scotland, early in the year 1862, he said:—

"The mechanical advantages to be derived by the adoption of surface condensation are:—

"I. Freedom from all unsafe deposits on those internal parts of boilers exposed to severe heat.

"II. The use of boilers of improved construction, and suitable for steam of higher pressure.

"III. The use of the foulest water for condensing purposes, without incurring any risk of injury to the engines or boilers.

"IV. Increased regularity of feed to the boilers, and consequently less risk of injury to them from a deficiency of water.

"V. Increased uniformity of load on the air pump, rendering it unnecessary for the engineer in charge to reduce the injection or condensing water in heavy weather.

"It is believed those five advantages include all of importance as affecting safety or convenience, so far as the past and present experience can guide us. Each of them will be referred to in detail.

"1. FREEDOM FROM UNSAFE DEPOSIT, &c.—This is a natural result of the separation of the condensing water from the condensed steam, and what is now required is actual results from the longest experience. This past Christmas a steamer fitted in August, 1857, with a new boiler and surface condenser, was carefully examined, and a report made on its actual condition. This report will be found in another part of the paper. Here it is only necessary to state that there has never been any necessity to scale the interior plates, as is usual with salt-water boilers. In other instances of shorter experience the same freedom from inconvenient scale or deposit has existed.

"II. The Use of Higher Pressure, &c.—Of this there cannot be a doubt, as the general introduction of high pressure steam into sea-going steamers is prevented chiefly by the necessity of providing for the removal of scale and incrustation, and thus rendering it almost impossible to stay the boilers for a high pressure. All that is required to give an onward movement to high-pressure marine engines is an increased experience of, and confidence in, the preservation and durability of the boilers. Even already surface condensation and high-pressure steam of from 40 lb. to 120 lb. pressure have gone hand in hand across the Atlantic and up the Mediterranean.

"III. The Use of Foul Water for Condensing, &c.—This is a real vantage ground, and one of the most hopeful features of surface condensation. Engineers are well aware that even pure land water is almost unknown; that many of our largest manufacturing works are situated near the sea, or where the most serious effects are produced on the boilers from impure feed-water; that boiler incrustation is a constant source of complaint and reference at the meetings of the Manchester Steam Boiler Association; and that many of the rivers in India and abroad are little better than liquid mud or sand. These facts, with numberless others to the same effect, are well known to practical engineers. Surface condensation steps in, and, like the magician's wand of old, converts impurity into purity, or enables the engineer to do so, which is the same thing in effect. At the present time the author is fitting seven surface condensers of 650 total horses' power to land engines where the river water is impure. The condensers are being made in consequence of the success of one that has been working for the past twelve months.

"IV. Regularity of the Feed-Water.—With marine engines at sea, working with injection condensers, it requires constant and anxious attention to maintain a proper balance between the proper quantity fed into the boiler and that blown out; and many a good boiler has been ruined by neglect on this point. With surface condensers, except in cases of priming, the necessity for blowing out scarcely exists, and the regularity of the feed is a source of increased safety and great relief to the engineer in charge. On several occasions the author has run at sea from twelve to eighteen hours without making any alterations in the feed valve arrangements.

"V. INCREASED UNIFORMITY OF LOAD ON AIR PUMP.—This advantage can only be thoroughly appreciated in heavy weather at sea. With an injection condenser in a sea way, unless sudden changes in the speed of the engines are met by corresponding changes in the amount of condensing water supplied, there is a danger of the air pumps being overloaded, and the giving way of the discharge valve is often the result, endangering the safety of the ship. With surface condensers it is quite unnecessary to stand by to regulate the supply of condensing water in heavy weather; and, in a strong sea in the Atlantic, the author has known days pass without the water-regulating valve being touched.

"Those who are practically acquainted with the working of steam engines, especially marine engines, can appreciate the value of the advantages referred to as incidental to the use of surface condensers; and it must be admitted that the most favourable view has not been taken; for, among other advantages not named, may be mentioned that of the reduced size of air pump. This has not been referred to at present for two reasons—first, the reduction in size is partly counterbalanced by the addition of the circulating pump; and, secondly, the matter is referred to in a subsequent part of the paper.

"It is now proposed to consider the mechanical disadvantages incidental to the adoption of surface condensation. They may be divided under five heads:—

"I. The necessity for an additional pump, pumps, or other machinery for circulating the condensing water.

"II. The additional space required for the surface condenser, and also in some cases for the condensing water pump or machinery.

"III. The alleged tendency to corrosion in the boiler when working with water supplied from surface condensers.

"IV. The complication arising from a multiplicity of tubes or sheets forming the surface condensers.

" V. The increased liability to leakage from the number of tubes or other joints in the condensers.

"I. ADDITIONAL PUMP, &c.—It cannot be denied that whatever plan of circulating the condensing water may be adopted (when a high vacuum is required), it is and must be additional to the air and feed pumps. There is, however, some compensation in this case, inasmuch as it has been proved, by indicator diagrams, that the total load on the air and circulating pumps is less than that on the injection air pump, allowance being made for the difference in the capacity of the two air pumps; and experience has proved that, with surface condensation, the same vacuum can be obtained with one-half the capacity of air pump required with an injection condenser.

" Mr. Spencer next gave three cases of comparison, showing the vacuum actually obtained, and the capacity of air pumps on the two systems. These, being well-certified cases, are repeated here in illustration of the preceding remarks.

Steamship.	H. P.	INJECTION.		SURFACE.	
		Air pump. (Per minute.)	Vacuum.	Air pump.	Vacuum.
		Cubic feet.	Inches.	Cubic feet.	Inches.
No. 1 . .	50	70	23	45	24·5
„ 2 . .	100	350	23	200	24·5
„ 3 . .	400	1,100	25	500	27·5

" As a further illustration may be mentioned the 500-horse power engines of H.M. frigate 'Arethusa,' fitted by Mr. Penn, with the author's plan of surface condensers. On trial with air pumps about one half the usual capacity for engines of equal power, a vacuum of 26·5 in. was obtained.

"In the only case where the author had an opportunity of correct comparison with the same engines, it was found that with 1½ in. better vacuum, the load on the air and circulating pumps was about 10 per cent. less than that in the injection air pumps.

"All these facts, resulting from actual experience, being duly considered, the disadvantage of the additional pump is reduced to a minimum, and confined to its being simply an additional piece of machinery involving no increased duty.

"II. ADDITIONAL SPACE OCCUPIED.—In many cases the additional space required in the engine-room for the surface condenser and pumps has militated considerably against the system. A very slight consideration, however, will somewhat paradoxically change this disadvantage into an advantage. It is quite true that more space is required for the surface condenser on board ship; but what benefits are derived from its use? Taking the lowest estimate, a saving of 15 per cent. of fuel is realised. Take a case in actual practice—injection engines requiring 45 tons per day for a ten days' voyage, making a total stowage of 18,000 cubic feet. Now, attach to these engines surface condensers occupying an additional space, say, of 300 cubic feet, and we will make no deduction for the space occupied by the injection condenser—the saving of space for the voyage will be 15 per cent. of 18,000 cubic feet, equal to 2,700 cubic feet. It now becomes simply a credit and debit account: credit surface condensation with 2,700 cubic feet of space saved, and debit surface condensation with 300 cubic feet occupied, we have then a balance of 2,400 cubic feet in favour of surface condensation. Strictly speaking, in many cases the balance will be even more favourable. It is evident, therefore, the alleged disadvantage becomes an important element of economy of space when the whole question is fairly considered. Credit will also frequently have to be given for reduced diameter of cylinders and bulk of boilers. With the present limited experience of the actual economy resulting from surface condensation alone, and the well-known facility with which steamship proprietors claim all improvements, and, at the same time, insist on having as big engines and boilers as ever, the author has preferred abstaining from raising hopes that may not be realised for many years.

"III. The Alleged Tendency to Corrosion.—This is undoubtedly the most serious charge that can be brought against the system of surface condensation; and, if proved to any serious extent, will render its success exceedingly doubtful. That there is an element of truth in this most serious objection to the fresh-water system experience has proved. Cases have occurred—both in America and in this country—where boilers supplied with water from surface condensers have corroded much more rapidly than boilers working with salt water. In making this admission, however, the advocates of surface condensation are fully aware that this corrosion has not occurred in all cases; and not only so, it is also believed that, with the present knowledge on the subject, such corrosion might have been prevented. In the cases of corrosion that have come under the personal observation of the writer, its appearance has been that of a honeycombed action on the plates and tubes, of some deleterious substance held in solution by the water, and deposited in showers. These circumstances have chiefly given rise to the opinion that portions of the metal from the condenser tubes, and steam and feed pipes, have been carried into the boilers, and gradually accumulated in sufficient quantities to act on the iron plates and tubes of the boilers. But as the galvanic or chemical action between copper and wrought iron is generally due to the presence of salt in the water, and as no serious injury arises from the presence of brass tubes in boilers, there is some difficulty in thus accounting for the corrosion, more especially as it has been found most severe when the water has been the purest. There is much difficulty in explaining the true cause of the corrosion, but the causes alleged will be stated, with a few remarks on each, and any experience of the author's that bears on the subject. All those who are interested in the success of surface condensation are appealed to to contribute their experience on this most important question. If there exists an evil that cannot be remedied, let it be known as such. The true spirit of engineering seeks to benefit mankind, and not to perpetuate a system that is no improvement on its predecessor.

" There are two principal causes alleged as producing corrosion in distilled water boilers :—

" 1. A softening effect of pure soft water, without any mineral hardness in it.

" In support of this view cases have repeatedly occurred where wrought-iron boilers fed with soft land water have been destroyed in six months. Cases have occurred in the neighbourhood of Newcastle-on-Tyne. The only remedy for this would be chemically to counteract this injurious action, or at sea to mix with the pure water a portion of sea water.

" 2. Chemical or galvanic action from the presence of copper in the boiler, conveyed there in the water or grease from the steam and feed pipes and condenser tubes.

" From careful observation the author has formed his own opinion on the cause of corrosion, and is regulating his practice in accordance with it. He thinks that, although in some cases the excessive purity of water may be hurtful, the chief cause of corrosion is the want of change in the water, thus allowing of an accumulation of particles of copper from the condenser tubes, and chiefly from the steam and feed-pipes, until the solution is sufficiently strong to affect the iron. The mixture of a small portion of salt water, sufficient to produce a gradual change of water, has been found to prevent any serious corrosion, as well as to check it when it has commenced. No appreciable loss of economy of fuel will be caused by this plan, and it relieves the engineer from any necessity of supplying the waste of pure water occurring in surface condensation, by a reserve on board. It may also be found desirable to tin the steam side of the condensing surface, as well as to substitute iron for copper steam and feed pipes.

"Having thus glanced at the gloomy side of this barrier to the general adoption of surface condensation, the inquiry is made whether any boilers have met a violent death, or been consumed in say from twelve to eighteen months, or even two years? To this inquiry we may cheerfully and decidedly reply in the negative. In America, it is said, some boilers have died very young from surface condensation; but as the informants have not supplied date of birth or death, symptoms of illness, or appearance of the body after death, nor given us the results of any *post mortem* examination, we shall act wisely in waiting for more accurate information. In England present experience in boilers fed with water from surface condensers is very limited and short-lived. Speaking generally, there is no authenticated case of a boiler worked with distilled water that has suffered more, permanently, from corrosion, than boilers fed with sea water, while there are instances of their suffering much less from corrosion than salt water boilers.

"As stated previously, a small steamer was fitted with a new boiler and a surface condenser in August, 1857, and the following is a correct report of the state of this boiler at Christmas just past:—

"**Newhaven, Sussex, 18th January, 1862.**

"I. S. steamer 'Alar,' 50-horse power, fitted with a new boiler and Spencer's surface condenser in August, 1857. Distance steamed to this date, 100,000 knots; steam pressure 40 lb.; waste made up with sea water.

"Condition of boiler examined this day by the undersigned:—

"*External cylindrical shell* in sound and efficient condition externally and internally.

"*Furnaces*, externally and internally in good condition, and apparently equal to new.

"*Flame chamber*, top, sides, and back in good condition, and no signs of wasting. A small patch, 8 in. by 3 in., wanting at bottom, where plate is thinned by a leaky rivet.

"*Tube plates*, sound, and in good condition; quite equal to that of the external shell.

"*Tubes*, 148 iron tubes, 3¼ in. in diameter; not ferruled: 8 tubes have been renewed, and the remainder will require renewal this year.

"*Stays.*—The long shell stays, angle iron, &c., as far as can be seen, do not require renewal, many of them being in a perfect condition. The two upper rows of screwed stays at the back of the flame-box were renewed in April, 1861. A few of the screwed stays in furnace water spaces are wasted, and require renewal; but it is believed the waste has been caused chiefly, if not entirely, by the wash of the water and grit when the ship rolls. The remainder of the screwed stays are in good condition.

"*Uptake.*—As far as can be ascertained the plates and rivets are in good condition, and not wasted.

"(Signed) EDWARD FOWLER,
"*Superintendent.*
"J. JOHNSON,
"*Chief Engineer.*

"The following is a report on the condition of a 100-horse power boiler attached to a pair of the author's surface condensing marine engines. The boiler has been twelve months working:—

"*Boiler.*—Apparently as good as new. There was a very thin scale of salt on the furnace crowns and tubes. The flat part of uptake was covered with a deposit of tallow and mud to the thickness of 2 in. The uptake does not appear to have suffered any damage by the deposit thereon. A few of the top stays are a little corroded. That I consider is due to the wash.

"(Signed) WILLIAM DIXON.
"*Manager to Messrs. R. and W. Hawthorn.*

"December 26, 1861.

"To these reports is added a third of four London made boilers working with injection condensers, and having steam up on an average of seven hours a day, for four days in each week.

"Report on the condition of four boilers started at Christmas, 1856—25 lb. steam, and distance run under steam, 65,000 knots:—

"Newhaven, January, 1862.

"Uptakes renewed in the autumn of 1859; also the stays and angle irons at uptake end; top shell of boilers partly replated.

"*Christmas*, 1861.—Uptakes thickened with ¼ in. plate, new angle iron, and stay ends at uptake; new bottoms to shell; several patches in furnace crowns; 250 screwed stays renewed in each boiler; 240 brass tubes to be taken out of each boiler to scale the tube plates and tubes; these tubes pierced up and replaced.

"(Signed) EDWARD FOWLER,
"*Superintendent.*

"One conclusion is certain, that while there is no occasion for alarm on this subject of corrosion, practical men cannot be expected to endorse many of the extreme statements published in favour of surface condensation; such as these—that land boilers last seven times as long as marine, and that boilers worked with distilled water last three times as long as those working with salt water. Such statements only retard the progress all so earnestly wish for. Even supposing that boilers supplied with water from surface condensers only last the same time as those fed from injection condensers, the advantages of the surface condensing system are overpowering.

"IV. THE DISADVANTAGE OF COMPLICATION.—On this head little can be said. It is a decided disadvantage, although practically it will be found of little importance when compared with the credit side of the account. The introduction of the multitubular boiler was objectionable on the same grounds; but, nevertheless, it has been found that the advantages greatly predominate.

"V. THE INCREASED LIABILITY TO LEAKAGE IN THE CONDENSER.—This disadvantage is one that can only be rightly valued from a more extended experience. If, after a number of years, it is found that surface condensers are as tight as when new, the disadvantage arising from a multiplicity of joints is only imaginary. At present it may be conceded as a practical objection. There is much reason to believe that a surface condenser, made and jointed on a correct principle, will become less liable to leak as it gets older. In the opinion of the author, facilities for examination and repair, together with extreme simplicity and fewness of joints, are the desiderata for all surface condensers. Practical experience will correct many of the mistakes in the plans of surface condensers now being made, and theoretical perfection must be made to give place to practical simplicity. In saying this the author does not for one moment presume to intimate that he has solved the problem; on the contrary, his experience leads him to seek rather than to offer advice.

It is now proposed to consider the economical advantages and disadvantages of surface condensation.

"ECONOMICAL ADVANTAGES.—1. THE SAVING OF THE FUEL WASTED IN BLOWING OUT A SUFFICIENT QUANTITY OF HEATED WATER AND STEAM TO AVOID UNSAFE DEPOSIT.—The amount of this saving in actual practice ranges from 15 to 25 per cent., and is an advantage in sea-going steamships that cannot be disputed, nor has it, in fact, ever seriously been so. That the amount of this saving cannot be correctly estimated by calculation is undoubted; and the author, from much consideration and observation, is confirmed in his opinion previously expressed to this institution, that in blowing out from, or just under the surface of the water in the boiler (the usual practice), much additional waste of heat occurs from the mixture of the steam and its latent heat with the water that is discharged by the scum-pipe.

"2. THE INTRODUCTION OF HIGH-PRESSURE STEAM, AND CONSEQUENTLY THE ECONOMY RESULTING FROM INCREASED EXPANSION.—It is impossible at present to say to what extent the introduction of surface condensation will immediately affect the increase of the working pressure. In all probability no general move will be made in this direction until it is ascertained what reliance can be placed on the durability of the boilers worked with fresh or distilled water. Those engineers who have so perseveringly striven to introduce high pressure steam, with its attendant economy, deserve the best wishes of all who are earnest in steam engine improvement; and it is matter of sincere congratulation that they will now have the powerful aid of surface condensation. Their success, or rather the success of the system they advocate, is only a question of time.

"3. THE SAVING OF LABOUR IN CLEANING BOILERS, AS WELL AS THE SAVING OF REPAIRS AND RENEWALS.—Of the saving of labour in cleaning boilers supplied from surface condensers there can be no doubt. The saving in repairs and renewals can only be credited when experience has proved its value.

"4. THE SAVING OF FUEL ARISING FROM KEEPING THE BOILERS FREE FROM ANY THICK SCALE OR INCRUSTATION.—It is well known with ordinary injection engines the supply of steam gradually lessens each year, whilst a larger amount of fuel is consumed to obtain the diminished supply. This waste and loss is entirely obviated with surface condensation, as the amount of scale formed, with a considerable mixture of salt water, is quite insufficient to cause any appreciable loss of steam or waste of coal.

"These four enumerated sources of economy in surface condensation are the most prominent and evident among many other incidental ones. Their exact monetary value cannot be given.

"It remains now only specifically to allude to those disadvantages of surface condensation that tend to increase the cost of steam power.

"1. AN INCREASED FIRST COST OF MACHINERY, VARYING FROM 10 TO 20 PER CENT.—It has been asserted that the same amount of power will cost less with surface condensers than with the ordinary system, and for the reason that half the boiler power can be saved; and this statement is further supported by reference to a steamer in which it is said the same duty is realised from half the usual boiler power. The writer of that statement is most decidedly deceiving himself. Steam engines fitted with surface condensers cannot be made for the same money as those fitted with injection condensers. The average saving in steam or heat by surface condensation cannot be fairly taken at more than 20 per cent., or one-fifth, and it follows, therefore, that only one-fifth of the boiler power can be saved, and this amount of saving will only represent one-third or one-half of the extra cost of the surface condensers. That steam engines fitted with surface condensers and other improvements in machinery and boilers tending to economy of fuel may ultimately be profitably made, per indicated horse power, at a price as low as, or even lower than that now charged, is not only possible, but highly probable.

"At the same time every steam engineer is aware there are circumstances connected with the introduction of improvements for economising fuel that tend to increase the first cost of steam power, the user, nevertheless, receiving a larger return on his outlay by the reduced consumption of fuel.

"2. THE INCREASED COST OF REPAIRS TO THE ADDITIONAL MACHINERY AND THE CONDENSER.—This increased cost will be slight, and is not worthy of serious consideration.

"Having thus briefly stated the advantages and disadvantages, mechanical and economical, incidental to the adoption of surface condensation, it only remains to touch on one or two points that have escaped notice, and then, in conclusion, to sum up the whole.

"How much surface is required, per indicated horse power, is a question often asked, and the merits of various plans of condensers are decided by the amount of surface each requires per indicated horse power, without any regard to the degree of expansion or the mode of using the steam. It is quite useless to compare the surfaces of a condenser receiving steam expanded fourteen or sixteen times with that of one where the steam is expanded twice or thrice; and, for the same reason, the bulk or space occupied by condensers cannot be compared without making due allowance for the mode of working the engines. For instance, with steam expanded ten times, one-third less condensing surface (about) should be required per indicated horse-power than when expanding once. The duty of the condenser is to be decided only by the weight of steam condensed per interval of time.

"Furthermore, as the efficiency of a surface condenser bears a proportion to the difference of temperatures of the condensing and condensed water, in all cases more water is required to condense an equal weight of steam by surface than by injection. In a surface condenser, if a small surface is used, the discharging temperature of the condensing water must be low and the quantity large. With a large surface the reverse will be the case. But, practically, it is impossible to assimilate the temperatures of the discharged condensing water and that of the condensed steam, as is the case in an injection condenser.

"In summing up it will be stated what condensing surface the author has found effective in cases where the steam is cut off at one-third, equivalent to expanding twice, and where either steam jackets or superheaters are adopted.

"The conclusions intended to be drawn from the preceding observations are—

"1. That a positive and decided saving of fuel, varying from 15 to 25 per cent., may in all cases be realised by the substitution of surface for injection condensers in sea-going steamers.

"2. That in all cases where water is foul or impure, and can be obtained in sufficient quantity, surface condensers ought to be adopted.

"3. That present experience does not warrant the durability of boilers, worked with surface condensers, to exceed that of those fed with salt or impure water, by more than 50 per cent.

"4. That all serious corrosive action in boilers worked with surface condensers can be prevented by a gradual but sufficient change of water without seriously affecting the saving of fuel.

" 5. That at present surface condensers add from 10 to 20 per cent. to the first cost of marine steam engines.

" 6. That one-half the capacity of air pump is sufficient to obtain any given vacuum when surface condensers are substituted for injection condensers.

" 7. That with an expansion of twice and superheated steam or steam-jackets, one-half the boiler surface is ample for the condensing surface.

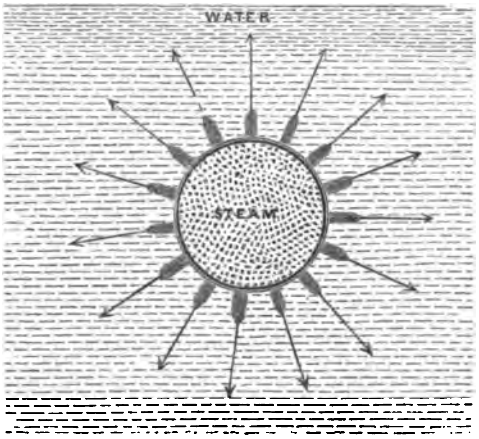
" 8. That in all cases a larger amount of condensing water is required for surface than for injection condensers.

" 9. That when surface condensers are adopted the boiler power may be safely reduced one-fifth, without any loss of indicated power."

Agreeing as we do in the main with Mr. Spencer, who is one of our best practical authorities on this subject, there are one or two points in the matter that require " finishing off," which we will do in our best way, treating first of the differences in condensing steam inside and outside the tubes.

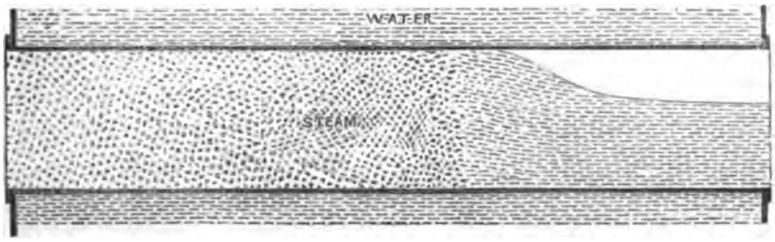
When the steam is inside the tube, the action of condensation is as illustrated by Fig. 209, in which case the heat is radiating *from* the tube into the water, and thus the steam is condensed in the tube and resumes its normal condition as when put into the boiler as feed water. The process of condensation in the length of the tube is illustrated by Fig. 210, where it will be seen that the steam begins to change its form at about half the length of the tube, and that at about a quarter of its length water is formed, and the upper part of the tube, for that length, is unfilled. From those evidences we know that steam, when inside the tubes, begins to condense at about midway of their length, and is formed into water before leaving them, when the position and dimensions are proportionate to those circumstances; the dimensions being 4 ft. 6 in. as a minimum, and 6 ft. as a maximum, the mean of which is 5 ft. 3 in., which is the proper length for a condensing tube when vertically situated, but if at an angle a decrease of length of one-sixth might be used with advantage. The reason for those two lengths being, that as with the vertical tube the steam condenses and falls by its gravity to the bottom, a shorter time is allowable for the process of condensation; whereas when the tube is angularly placed, the condensed steam rather trickles than falls to the air-pump end of the tube, and thus a longer time is allowed.

FIG. 209.



Burgh's transverse diagram of the practical actions of Water and Steam, when the Steam is inside and the Water outside the Tubes; illustrated first in a Lecture by him at the London Society of Arts and Sciences in the year 1867.

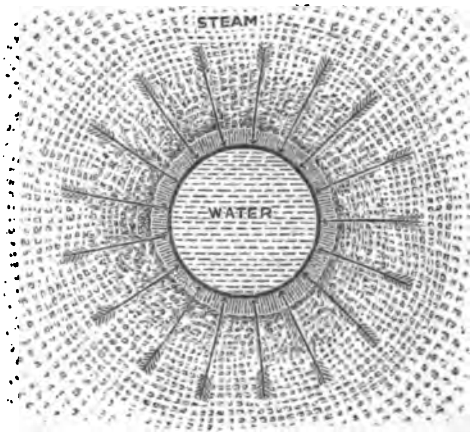
FIG. 210.



Burgh's longitudinal diagram in connection with Fig. 209.

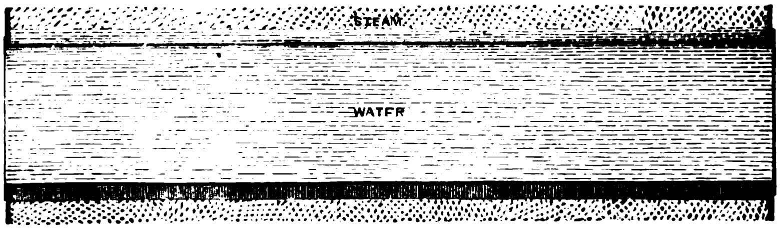
Taking into notice next the result of the water being inside the tubes and the steam outside, as illustrated by Fig. 211, the evidence here is that the heat concentrates *towards* the tube because the cooling property is within the same, while during its traverse it takes away the heat and thus condenses the steam directly around the tube. The horizontal action of this is illustrated by Fig. 212, where it can be seen that the steam at the upper part of the tube falls on it, and the steam at the lower part falls from the surface, so that the tube situated directly below receives the partially condensed steam when the tubes are horizontally situated. But when the vertical position is used, the steam needs much more time for condensation, because the spaces between the tubes are clear for the steam as a vapour and water to pass down amongst them, without any obstruction.

Fig. 211.



Burgh's transverse diagram of the practical actions of Water and Steam, when the Steam is outside, and the Water inside the tubes, in surface condensers; illustrated first in a Lecture by him at the London Society of Arts and Sciences in the year 1867.

Fig. 212.



Burgh's longitudinal diagram in connection with Fig. 211.

The length of vertical tubes for outside condensation should be 8 ft. as a maximum, and 5 ft. as a minimum, thus making a mean of 6 ft. 6 in.; but with horizontal tubes the maximum length should be 10 ft. and the minimum 7 ft., thus causing an average of 8 ft. 6 in. Those various lengths of tubes in all cases have been taken from practical results.

CIRCUIT OF THE CIRCULATING WATER FOR SURFACE CONDENSERS.—In this matter the first consideration is the position for the supply opening for the first admittance of the water, and the general practice is at the base of the tube compartment, from the belief that the hottest steam should be cooled by the warmest water, by which means a more rapid affinity occurs than if the extreme limits of temperature were connected. This arrangement has been illustrated fully in this work, both for outside and inside condensation, where it will be seen that the water enters at the bottom and passes out at the top of the tubes, or their compartments, as the case may be.

Our belief in this matter is, that to cause an equal distribution of the circulating water when it is to be amongst or in between the tubes, the supply opening should be centrally of their length and group, with two discharge openings, one at each end in opposite directions, from which positions the water would traverse out equally in two directions at the same time, in uniformity with the high and low temperature of the steam. And in the case of the water passing through horizontal tubes, it should be similarly treated, by four groups of tubes, the two upper receiving the water from above, and the two lower from below at the end compartments. This would equalise the temperature of the water more, and certainly cause a better vacuum than the forward and backward and return traverse now so generally used; or a reverse arrangement of openings might equally and advantageously be carried out, by having a supply opening at each end and the discharge opening centrally placed. Of course the practical reason for the most general traverse is, that the compartment into which the water is *forced* will be always *full* by that operation, or apparently more so than if the water were raised to the top and the discharge assisted, by the gravity or weight of the volume descending through or amongst the tubes, and from thence overboard.

According to M. Peclet, the cooling properties of polished metals for the condensation of steam are :—

Water Temperature.	Material.	No. of pounds of Steam Condensed per square foot per hour.	
68° to 77° Fahr.	Copper	21·5	On very thin metal tubes.
„ „	Brass	18·75	
Air 60°	Copper	0·28	
„	Sheet Iron	0·36	
„	Tin Plate	0·21	

And according to Joule, copper tubes will condense 100 lbs. of steam per square foot per hour.

CHAPTER XVIII.

RULES AND TABLES FOR PRACTICAL USE.

Proportions of Condensing Apparatus for Land Beam Engines.—Cubic contents of injection condenser =

$$\frac{\text{Cubic contents of the engine cylinder}}{6 \text{ to } 7}.$$

Cubic contents of air pump (single-acting) =

$$\frac{\text{Cubic contents of the engine cylinder}}{6 \text{ to } 7}.$$

Diameter of air pump rod $= \frac{\text{Diameter of air pump}}{6 \text{ to } 8}.$

Area of suction valve = Area of air pump × ·64.

Area of piston valve = Area of suction valve.

Area of discharge valve = Area of air pump × ·75 as a minimum.

Area of injection water pipe in square inches, temperature about 50° to 60° = Cubic contents of cylinder in feet × the exhausting pressure of the steam per lb. per square inch used as decimals.

Another rule is—

Area of injection pipe in square inches = Number of cubic inches of water per cubic foot of steam at exhausting pressure × Cubic contents of cylinder in feet × 5 to 6 [÷ 60].

The origin of this rule is, that to condense steam to cause a vacuum of 14 lbs., it requires five to six times as much injection water at 60° Fahr. as the water in the steam.

TABLE of Saturated Steam at different Pressures.

Actual pressure of the Steam exclusive of the Atmospheric Pressure.	Temperature in degrees of Faht.	Elastic force in inches of Mercury.	Cubic inches of Water to produce 1 cubic foot of Steam.	Volume of Steam produced from one of Water.	Weight of one cubic foot of Steam in lbs.
lbs.					
1	216·3	32·64	1·099	1572	·0397
2	219·5	34·68	1·162	1487	·0419
3	222·5	36·72	1·226	1410	·0442
4	225·4	38·76	1·287	1342	·0465
5	228·0	40·80	1·350	1280	·0487
6	230·6	42·84	1·411	1224	·0510
7	233·1	44·88	1·474	1172	·0532
8	235·5	46·92	1·536	1125	·0576
9	237·9	48·96	1·597	1082	·0598
10	240·2	51·00	1·658	1042	·0620
11	242·3	53·04	1·719	1005	·0642
12	244·4	55·08	1·779	971	·0664
13	246·4	57·12	1·840	939	·0686
14	248·4	57·16	1·910	909	·0707
15	250·4	61·20	1·959	881	·0729
16	252·2	63·24	2·021	885	·0751
17	254·1	65·28	2·079	830	·0772
18	255·9	67·32	2·138	807	·0794
19	257·6	69·36	2·198	785	·0815
20	259·3	71·40	2·258	765	·0837
21	260·9	73·44	2·316	745	·0858
22	262·6	75·48	2·376	727	·0879
23	264·2	77·52	2·433	709	·0900
24	265·8	79·56	2·493	693	·0921
25	267·3	81·60	2·552	677	·0942
26	268·7	83·64	2·610	661	·0963
27	270·2	85·68	2·670	647	·0983
28	271·6	87·72	2·725	634	·1004
29	273·0	89·76	2·787	621	·1025
30	274·4	91·80	2·842	608	·1046
31	275·8	93·84	2·899	595	·1067
32	277·1	95·88	2·958	584	·1087
33	278·4	97·92	3·015	573	·1108
34	279·7	99·96	3·074	562	·1129
35	281·0	102·00	3·130	552	·1141
36	282·3	104·04	3·188	542	·1150
37	283·6	106·08	3·248	532	·1170
38	284·7	108·12	3·304	523	·1192
39	285·9	110·10	3·361	514	·1212
40	287·1	112·20	3·415	506	·1232
41	288·2	114·24	3·465	498	·1252
42	289·3	116·28	3·526	490	·1272
43	290·4	118·32	3·585	482	·1292

Actual pressure of the Steam exclusive of the Atmospheric Pressure.	Temperature in degrees of Faht.	Elastic force in inches of Mercury.	Cubic inches of Water to produce 1 cubic foot of Steam.	Volume of Steam produced from one of Water.	Weight of one cubic foot of Steam in lbs.
lbs.					
44	291·6	120·36	3·645	474	·1314
45	292·7	122·40	3·700	467	·1336
46	293·8	124·44	3·756	460	·1356
47	294·8	126·48	3·814	453	·1376
48	295·9	128·52	3·865	447	·1396
49	296·9	130·56	3·927	440	·1416
50	298·0	132·60	3·981	434	·1436
51	299·0	134·64	4·037	428	·1456
52	300·0	136·68	4·094	422	·1477
53	300·9	138·72	4·143	407	·1497
54	301·9	140·76	4·204	411	·1516
55	302·9	142·80	4·256	406	·1535
56	303·9	144·84	4·309	401	·1555
57	304·8	146·88	4·363	396	·1574
58	305·7	148·92	4·419	391	·1595
59	306·6	150·96	4·476	386	·1616
60	307·5	153·00	4·535	381	·1636
61	308·4	155·04	4·583	377	·1656
62	309·3	157·08	4·645	372	·1675
63	310·2	159·12	4·695	368	·1696
64	311·1	161·16	4·747	364	·1716
65	312·0	163·29	4·812	359	·1736
66	312·8	165·24	4·867	355	·1756
67	313·6	167·28	4·923	351	·1776
68	314·5	169·32	4·965	348	·1795
69	315·3	171·36	5·023	344	·1814
70	316·1	173·40	5·082	340	·1833
71	316·9	175·47	5·127	337	·1852
72	317·8	177·48	5·189	333	·1871
73	318·6	179·52	5·236	330	·1891
74	319·4	181·56	5·300	326	·1910
75	320·2	183·60	5·439	323	·1929
76	321·0	185·64	5·400	320	·1950
77	321·7	187·68	5·451	317	·1970
78	322·5	189·72	5·520	313	·1990
79	323·3	191·76	5·574	310	·2010
80	324·1	193·80	5·628	307	·2030
81	324·8	195·84	5·665	305	·2050
82	325·6	197·88	5·721	302	·2070
83	326·3	199·92	5·779	299	·2089
84	327·1	201·96	5·837	296	·2108
85	327·8	204·00	5·897	293	·2127
90	331·3	214·20	6·150	281	·2218
95	334·6	224·40	6·424	269	·2317
100	338·0	234·60	6·672	259	·2406

The use of the foregoing table for practical purposes is this:—Suppose the capacity of a cylinder is 80 cubic feet, and the steam is cut off from it when the piston has made ¼th of the complete stroke, then $\frac{80}{4} = 20$ cubic feet of space, which is the amount of steam contained in the cylinder during one stroke of the piston. We will imagine that the *full* pressure of the steam is 60 lbs. on the square inch, and next, that we require to know the amount of water which the steam in question represents. Looking at the table, we see that one cubic foot of steam at 60 lbs. pressure is produced from 4·535 cubic inches of water, then 20 × 4·535 = 90·7 cubic inches of water, in the form of steam, used *in the cylinder* for each stroke of the piston.

Next we must notice the elasticity of the steam, and its temperature corresponding with the pressure. Conclude, as an example, that the steam is 40 lbs. on the square inch, we shall see in the table that its temperature is 287·1°. Suppose the 40 lbs. to be the pressure in the boiler, and that it loses 5 lbs. on the square inch when reaching the cylinder, what will the loss of heat be? Here let 40 − 5 = 35; then 35 lbs. pressure, according to the table, = 281°, which shows that 287·1° − 281 = 6·1° loss of heat, or what is lost by radiation.

Imagine next that the steam, at 35 lbs. pressure, entering the cylinder, is cut off at ¼th of the stroke of the piston, and is exhausted at ¾ths of the stroke, what will be the reduction of the pressure at the point of exhaustion? The area of the cylinder is assumed as 20 feet, the stroke of the piston 4 feet; then 20 × 1 = 20 cubic feet, being the amount of steam in the cylinder when the supply terminated; the exhaustion occurring when the piston has reached 3 feet. Now, as the theoretical law which governs the rate of the expansion of steam is, that inversely as the cubical contents of the space in the cylinder for expansion increases, so will the pressure of the steam in it be reduced, supposing the supply to be cut off. This is founded on the law discovered by Boyle and Mariotte, who proved "that the volume of a given quantity of steam is inversely as the pressure it bears." For example, if steam, at 60 lbs. on the square inch, occupying 20 cubic feet, is expanded into 40 cubic feet, the pressure will be reduced to one-half, or 30 lbs.; which converts the following formula introduced by the author in his paper read at the Hall of the London Society of Arts, to the members, December 18th, 1867:—

"To the cubical contents for the supply, add the cubical contents for expansion; divide the total sum by the cubical contents for supply; the initial pressure of the steam, divided by the quotient, equals the pressure of the steam when expansion terminates. Now, let A = cubical contents for supply; B = cubical contents for expansion; C = initial pressure of the steam; and x = the pressure when expansion terminates; then, by the above formula, the symbols are thus arranged, $x = C \div \left[\frac{A + B}{A}\right]$; which, if put into the figures alluded to in the question, are thus—$\left.\begin{array}{r} A = 20 \\ B = 40 \\ C = 35 \end{array}\right\}$ $20 + 40$, then $\frac{60}{20} = 3$, and $\frac{35}{3} = 11 \cdot 666$ for the pressure of the steam when expansion is concluded."

It will, therefore, be understood that A = the area of the cylinder, × the length of the stroke of the piston during the supply of the steam, and that B = the length from the end of A, that the piston travels till exhaustion ensues, × by the same area, and that C is the maximum pressure of the steam in the cylinder.

Now, on referring again to the table, we shall find the relation that the volumes of the steam bear to each other under the two pressures named; at 35 lbs. the volume is 552, and at 11 lbs. the volume is 1005, and at 12 lbs. it is 971, so that the mean = $\frac{1005 + 971}{2}$, 988; therefore, 11·666 lbs. pressure corresponds with a volume of about 996; then $\frac{996}{552} = 1 \cdot 80$, which proves that the steam is reduced in rarefication in the proportion of as 1 is to 1·80, or that the saturation of the steam is 1·80 times more apparent at 11·666 lbs. pressure than at 35 lbs. on the square inch, while the temperatures are 243·4° and 281° respectively, showing a reduction of 37·6° of heat, radiation excepted.

PROPORTIONS OF MARINE INJECTION CONDENSERS AND FITTINGS FOR SCREW PROPELLER ENGINES.

Condenser.

$$\text{Cubic contents for one cylinder} = \frac{\text{cubic contents of cylinder}}{6 \text{ to } 7}.$$

$$\text{For two cylinders} = \frac{\text{cubic contents of cylinder} \times 1{\cdot}5}{6{\cdot} \text{ to } 7{\cdot}}.$$

Thickness of body = ¾ to 1¼ of an inch, being ribbed, and in some cases stayed for large engines.

Thickness of securing flanges = thickness of body × 1·25.

Thickness of doors = thickness of body × ·8 to ·6.

Diameter of securing studs = thickness of metal of doors.

Air Pumps.

$$\text{Cubic contents, double acting} = \frac{\text{cubic contents of cylinder}}{10{\cdot} \text{ to } 12{\cdot}}.$$

$$\text{Cubic contents, single acting} = \frac{\text{cubic contents of cylinder}}{6{\cdot} \text{ to } 7{\cdot}}.$$

Stroke of pump = stroke of engine.

Area of valves = area of pump × ·75 to ·8.

Valves.

These valves are discs of vulcanized india-rubber; the average diameter is about 6 to 7 inches, but it should never exceed 9 inches.

Thickness of valve = ½ to ¾ of an inch.

Lap of valve = thickness × ·5.

$$\text{Lift of valve} = \frac{\text{diameter}}{4}.$$

Valve Seating.

Thickness of flange = thickness of valve × ·8 to ·75.

Diameter of securing studs = thickness of valve.

Pitch of studs = diameter of stud × 8· to 7·.

Area of each small opening in seatings should never exceed 2 square inches.

Thickness of ribs = $\frac{1}{8}$ of an inch per square inch of opening.

Depth of ribs = $\frac{1}{8}$ of an inch per inch of extreme diameter of opening.

Diameter of securing bolts for guard = $\frac{3}{16}$ to $\frac{1}{8}$ of an inch per inch of valve's diameter.

Diameter of securing bolt boss in seating = diameter of stud + twice the lap of valve.

Radius of curve of guard = diameter of valve × ·6 to ·5, but in some cases the guard is angular.

Thickness of guard = $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

An approximate mode to obtain the effective area of the openings in one valve seating = area of the diameter of the opening × ·5 to ·7, the latter being for diameters from 5 to 7 inches.

$$\text{Total area of diameter of openings} = \frac{\text{effective area}}{\cdot 5 \text{ to } \cdot 7}.$$

Area for exhaust steam pipe for 2 cylinders = area of exhaust opening from 1 cylinder × 1·5 as a maximum, 1·25 as a minimum.

Area of exhaust (water) for 2 air pumps = total area of 1 set of valves for 1 air pump × 1·5.

Area of injection (sea-water) for 2 cylinders = cubic contents of 1 cylinder in feet × 1·5 as a minimum, 2 as a maximum × the pressure of steam per square inch used as decimals.

The bilge injection valve and piping is usually smaller than the sea injection, say about $\frac{1}{10}$th of the diameter deducted, will be the difference in the proportions. Now, as the "bilge injection" is to drain the bilges in the case of emergency, the bilge water should *not* enter the condenser, but the air pump only.

Air pump lining is usually of gun metal, secured either by a flange, with studs or a packing recess cast in the casing; in some cases studs of gun metal $\frac{1}{2}$ inch in diameter are recessed in the lining, and tapped into the casing; by this means the flanges and packing are dispensed with.

Thickness of lining = $\frac{1}{4}$ to $\frac{1}{2}$ an inch, with raised surfaces for turning and fitting.

Air pump piston, or plunger, is entirely of gun metal with metallic packing rings and studs, as illustrated by Fig. 108.

Depth of piston ring = diameter × ·3 to ·2.

Thickness of metal of body = $\frac{3}{8}$ to $\frac{1}{2}$ inch.

Thickness of ribs 4 to 6 = thickness of body × ·7 to ·6.

$$\text{Diameter of air pump rod} = \frac{\text{diameter of piston}}{6\cdot \text{ to } 7\cdot}$$

Area of snifting valve = 1 to $\frac{3}{4}$ of a square inch per foot of cubical contents of condenser.

Injection Valve.

This valve regulates the water from the sea by a Kingston valve The injection valve and casing are made entirely of gun metal, the valve and seat are of a gridiron shape, with 3 or 4 openings.

Length of openings = diameter of pipe.

$$\text{Width of each opening} = \frac{\text{area of one opening}}{\text{length}}.$$

Thickness of metal of body = $\frac{1}{4}$ to $\frac{3}{8}$ of an inch.

Thickness of flanges = thickness of body × 1·125.

Diameter of valve rod = $\frac{3}{32}$ to $\frac{1}{8}$ of an inch per inch of diameter of pipe.

Diameter of studs = $\frac{1}{2}$ to $\frac{3}{4}$ of an inch.

PROPORTIONS OF MARINE INJECTION CONDENSERS AND FITTINGS FOR PADDLE-WHEEL OSCILLATING ENGINES.

Condenser.

Cubic contents of condenser for 2 cylinders =

$$\frac{\text{Cubic contents of 1 cylinder} \times 1\cdot 5}{6 \text{ to } 7}.$$

Air Pump Vertical Action.

Cubic contents of air pump, single acting, when 1 is used = that of condenser.

Cubic contents of 1 air pump, single acting, when 2 are used $= \frac{\text{cubic contents of 1 cylinder}}{6\cdot \text{ to } 7\cdot}$.

Stroke of air pump = stroke of engine × ·5 to ·4.

Area of suction valves in piston = effective area of pump × ·4 to ·5, or as much larger as practical.

Diameter of connecting rod $= \frac{\text{diameter of air pump}}{7\cdot \text{ to } 9\cdot}$.

Diameter of pin for piston = diameter of connecting rod.

Thickness of trunk at neck = $\frac{1}{4}$ to $\frac{5}{8}$ of an inch, slightly tapering at the extremity.

Depth of stuffing box for trunk $= \frac{\text{diameter of trunk}}{4\cdot \text{ to } 5\cdot}$.

Depth of gland = depth of stuffing box × ·6 to ·7.

Thickness of gland $= \frac{\text{diameter of trunk}}{8\cdot \text{ to } 10\cdot}$.

Area of one cap bolt = area of connecting rod × ·25.

Thickness of keying socket $= \frac{\text{diameter of rod}}{3\cdot}$.

Area of injection pipe as for screw engines.

Kingston Valves.

This valve is used to allow the sea water to flow into the condenser, bilge, or boilers.

Diameter of valve = $2\frac{1}{2}$ to 9 inches, but from 4 to 6 inches is the most practical to keep water-tight and secure to the bottom of the ship.

Depth of valve $= \frac{\text{diameter}}{2\cdot \text{ to } 3\cdot}$.

Thickness of valve $= \frac{\text{diameter}}{6\cdot \text{ to } 8\cdot}$.

$$\text{Diameter of valve-guide's spindle} = \frac{\text{diameter of valve}}{5\cdot \text{ to } 7\cdot}.$$

Taper of side of cone inserted in ship = 2 to 3 in 12.

Position of guard = length of cone beyond valve × ·5.

Depth of guard = depth of valve.

Length of guide of valve spindle should allow the valve to open $\frac{1}{4}$ of the valve's diameter.

Thickness of guard = $\frac{1}{8}$ as a minimum for guards 3 inches in diameter, increasing, above this, $\frac{1}{8}$ of an inch per 2 inches of diameter.

Diameter of valve rod = $\frac{1}{4}$ to $\frac{3}{16}$ of an inch per inch of valve's diameter.

Thickness of body of casing = $\frac{3}{8}$ as a minimum for $2\frac{1}{2}$ inches in diameter, increasing, above this, $\frac{1}{8}$ to $\frac{1}{16}$ of an inch per inch of diameter.

Diameter of clip studs = diameter of valve rod × ·75.

Depth of clip = diameter of valve rod × 1 to ·75.

Length of handle 6 to 10 inches.

Diameter of handle 1 to $1\frac{1}{4}$ inch.

Discharge Water Valve and Casing.

Internal area of casing = area of extreme diameter of valve × 2.

Thickness of casing gun metal = $\frac{3}{8}$ of an inch for casing 12 inches in diameter, increasing $\frac{1}{4}$ of an inch per 6 inches of diameter.

Thickness of casing (cast iron) = thickness of that for gun metal × 2 to 1·75.

$$\text{Thickness of valve} = \frac{\text{diameter of valve}}{10 \text{ to } 15}.$$

$$\text{Diameter of valve spindle} = \frac{\text{diameter of valve}}{8 \text{ to } 12}.$$

Proportion of the stuffing-box, gland, cover, flanges, and studs, as for steam cylinder.

MARINE SURFACE CONDENSERS.

By a happy coincidence, it is found in practice that the ratio of the cooling surface in square feet per nominal horse-power is nearly analogous with the pressure of the steam in pounds per square inch when it enters the condenser, as the following table indicates:—

BURGH'S TABLE of the total area of the tubular surface per nominal horse-power when the indicated horse-power = nominal × 5 to 6.

Pressure of steam on entering the condenser. lbs.	Degrees Fahr. of corresponding temperature of steam.	Ratio of tube surface in square feet per nominal horse-power.	No. of cubic inches of circulating water per stroke of the pump per square foot of tube surface.
1	216·3	1·25	5·96
2	219·5	2·31	5·60
3	222·5	3·31	5·27
4	225·4	4·28	4·95
5	228·0	5·15	4·66
6	230·6	6·02	4·37
7	233·1	6·85	4·10
8	235·5	7·60	3·84
9	237·9	8·45	3·52
10	240·2	9·22	3·30
11	242·3	9·91	3·07
12	244·4	10·61	2·84
13	246·4	11·28	3·61
14	248·4	11·95	2·39
15	250·4	12·58	2·18
16	252·2	13·21	1·97
17	254·1	13·85	1·76
18	255·9	14·45	1·56
19	257·6	15·01	1·37
20	259·3	15·58	1·18

From this table we produce the three following rules:—

Area of tube surface in square feet = ratio of tube surface × nominal horse-power.

Cubic contents of circulating water pump in inches = area of tube surface in square feet × number of cubic inches of water required according to the temperature of the steam when entering the condenser.

$$\text{Area of pump in square inches} = \frac{\text{cubic contents in inches}}{\text{length of stroke in inches}}.$$

The proportions of the valves, air pump, and fittings, &c., are as for the injection air pump as already given.

Together with those rules, the engineer must remember that the door openings should be as large as convenient to the arrangement of the pumps and valves: the minimum size for side openings being 9 inches high and 14 inches long, and for top or over-head openings, 12 inches wide and 18 inches long. The doors must be secured by studs and nuts of ⅝ths to ¾ths of an inch in diameter, and pitched at eight times the diameter. The thickness of the body of condensers should be ¾ths of an inch as a minimum and 1¼ inch as a maximum, and ribs should be introduced at all places where resistance is required. Of course circular and current portions require no ribs, but straight surfaces must be ribbed or stayed to be made sufficiently rigid.

The position of the snifting valve should be as low as the bottom of the condenser in all cases, and if below that, with a branch passage for more effectual draining, there will be the advantage of more rapidity of action.

The securing bolts for condensers should be about 1 to 1¼ inch in diameter for small sizes, and 1½ to 2 inches for large sizes, at a pitch of twelve times the diameter. The securing flanges should be three times the width of the bolts used, and ribbed between every two bolts, to ensure certain strength.

Cast iron is the general material for condensers, and these rules refer to that metal: but in some cases rolled brass sheets have been used for the bodies of cylindrical surface condensers, with a great reduction of weight, and we have known the pumps' and valves' casings of gun-metal, also for the same purpose; but where economy of primary outlay is demanded, the cast iron structure must be adopted as of old.

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